OBSERVE AND IMAGE **COMET ISON** AT ITS BRIGHTEST! p. 54

November 2013

Astronomy®

The world's best-selling astronomy magazine

SPECIAL ISSUE

Comet ISON BLAZES INTO GLORY



The science of comets p. 24

20 bright comets of the past 50 years p. 46

Comets throughout HISTORY p. 30

AMAZING ILLUSTRATION: Anatomy of a comet p. 44

Comet Hale-Bopp was the last Great Comet witnessed by Northern Hemisphere observers. Will Comet ISON surpass it in magnificence?

Preview November's African total solar eclipse p. 60

www.Astronomy.com

BONUS ONLINE CONTENT CODE p. 4

Vol. 41 • Issue 11

ENTER AND YOU COULD WIN $2,500

From the National Science Foundation, Division of Astronomical Sciences

GIVE US YOUR BEST SHOT!

Submit stunning images of Comet ISON for impressive cash prizes!

Astronomers predict ISON may become one of the best comets in decades. To commemorate this grand sky event, head out this fall to capture your finest images of Comet ISON, and you could win cash prizes and have your photo featured in *Astronomy* magazine.



ENTER TODAY!

Register and submit your Comet ISON images to **www.nsf.gov/comet.**

The photo contest runs October 15, 2013, through January 15, 2014.

DON KNABB (BOY & TELESCOPE); ANDY D'ARIENZO (PIGGYBACK CAMERA); GERALD RHEMANN (THROUGH THE SCOPE); DAMIAN PEACH (CAMERA AND TRIPOD)

National Science Foundation
Division of Astronomical Sciences

Astronomy magazine

Discover MAGAZINE

See **www.Astronomy.com/ISONphotos** for imaging guidelines and official contest rules.

WorldMags.net

WorldMags.net

CELESTRON



COMETRON 114AZ
Telescope

COMETRON FIRSTSCOPE
Telescope

COMETRON 7x50
Binocular

COMETRON 12x70
Binocular

ISON IS COMING—GET ON COMETWATCH!

CELESTRON COMETWATCH
For more information visit comet-watch.com

ISON, the "comet of the century," is streaking our way this fall, and Celestron has everything you need to catch this once-in-a-lifetime celestial event. With our new Cometron telescopes and binoculars, stargazers of all ages and experience levels can witness this legendary visitor from the cosmos. Don't get left in the space dust: get on CometWatch with Celestron!

CELESTRON PREMIER SELECT DEALERS

OPT Telescopes – 800.483.6287 – www.opttelescopes.com
B&H Photo – 800.947.9970 – www.bhphotovideo.com
Hands On Optics – 866.726.7371 – www.handsonoptics.com
Astronomics – 800.422.7876 – www.astronomics.com
Adorama – 800.223.2500 – www.adorama.com
High Point Scientific – 800.266.9590 – www.highpointscientific.com
Optics Planet – 800.504.5897 – www.opticsplanet.com
Telescopes.com – 888.988.9876 – www.telescopes.com
Focus Camera – 800.221.0828 – www.focuscamera.com
Woodland Hills – 888.427.8766 – www.telescopes.net

YOUR ADVENTURE STARTS HERE
WWW.CELESTRON.COM

WorldMags.net

Online Content Code: ASY1311
Enter this code at: **www.astronomy.com/code**
to gain access to web-exclusive content



CONTENTS

NOVEMBER 2013
VOL. 41, NO. 11



GERALD RHEMANN

ON THE COVER

A bluish tail of ionized gas and a yellow-white dust tail highlighted Comet Hale-Bopp in 1997. Observers hope Comet ISON puts on a similarly dazzling show this month.

FEATURES

24 COVER STORY
The science of comets
Scientists have sent 12 missions to explore comets. Here's what they've learned about these relics from the early solar system.
MATTHEW KNIGHT

30
Comets: From superstition to science
For thousands of years, scientists thought comets lived within Earth's atmosphere, and nearly everyone believed these celestial visitors delivered death and destruction with their tails.
GARY KRONK

36
The Sky this Month
ISON at its brightest.
MARTIN RATCLIFFE AND ALISTER LING

38
StarDome and Path of the Planets
RICHARD TALCOTT; ILLUSTRATIONS BY ROEN KELLY

44
Illustrated: Anatomy of a comet
Slip into a coma, sweep up a dust tail, and brace yourself against the solar wind. **SARAH SCOLES; ILLUSTRATIONS BY ROEN KELLY**

46
20 bright comets of the past 50 years
Each of these cosmic visitors of the past half-century told a unique story and captured the attentions of observers and imagers. **KARRI FERRON**

52
Ask Astro
Predicting a comet's path.

54
Comet ISON blazes into glory
This frozen ball of gas and dust puts on a show in the predawn sky. **RICHARD TALCOTT**

60
Totality crosses Africa
An eclipse shadow, exotic locations, and safaris will lure travelers to this event November 3.
JOEL K. HARRIS

64
A field trip to the stratosphere
Associate Editor **SARAH SCOLES** takes a ride with SOFIA.

COLUMNS

Strange Universe 10
BOB BERMAN
Observing Basics 14
GLENN CHAPLE
Secret Sky 18
STEPHEN JAMES O'MEARA

QUANTUM GRAVITY

Snapshot 9
Breakthrough 11
Astro News 12

IN EVERY ISSUE

From the Editor 6
Letters 10, 14
Web Talk 22
New Products 67
Advertiser Index 71
Reader Gallery 72
Final Frontier 74

Visit **Astronomy.com/toc** for bonus material — it's exclusive to *Astronomy* magazine subscribers.

Astronomy (ISSN 0091-6358, USPS 531-350) is published monthly by Kalmbach Publishing Co., 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Periodicals postage paid at Waukesha, WI, and additional offices. POSTMASTER: Send address changes to *Astronomy*, 21027 Crossroads Circle, P. O. Box 1612, Waukesha, WI 53187–1612. Canada Publication Mail Agreement #40010760.

ONLINE FAVORITES >>

Go to **www.Astronomy.com** for info on the biggest news and observing events, stunning photos, informative videos, and more.



The Sky this Week
A daily digest of celestial events



Trips & Tours
Travel the world with the staff of *Astronomy*



Seasonal Observing
Find great targets in your autumn sky



Picture of the Day
Astroimages from around the world

WorldMags.net

CELESTRON
UNIVERSALLY SUPERIOR

StarSense™ AUTOALIGN

YOUR TELESCOPE JUST GOT SMARTER.

Find thousands of stars, planets, galaxies, and more, even if you've never used a telescope before.

1 Attach StarSense AutoAlign with included hand control to your Celestron computerized telescope.*

2 Press ALIGN. Your telescope will guide you through the automatic alignment process in about 3 minutes.

3 Explore the Solar System and beyond with a custom sky tour based on your exact time and location.

Achieve the most accurate alignment possible with advanced mount modeling.

*Visit celestron.com/starsense for telescope compatibility



CELESTRON PREMIER SELECT DEALERS

OPT Telescopes – 800.483.6287 – www.opttelescopes.com
B&H Photo – 800.947.9970 – www.bhphotovideo.com
Hands On Optics – 866.726.7371 – www.handsonoptics.com
Astronomics – 800.422.7876 – www.astronomics.com
Adorama – 800.223.2500 – www.adorama.com
High Point Scientific – 800.266.9590 – www.highpointscientific.com
Optics Planet – 800.504.5897 – www.opticsplanet.com
Telescopes.com – 888.988.9876 – www.telescopes.com
Focus Camera – 800.221.0828 – www.focuscamera.com
Woodland Hills – 888.427.8766 – www.telescopes.net

www.CELESTRON.com

BY DAVID J. EICHER



The last really Great Comet

As we enjoy Comet ISON (C/2012 S1) at its best this month, comparisons will be made to the last really stunning comet, Hale-Bopp (C/1995 O1). On July 23, 1995, while observing the globular star cluster M70, two observers in the southwestern United States each stumbled on a fuzzy blob near the cluster in their eyepieces. In Cloudcroft, New Mexico, astronomer Alan Hale saw the comet, while 440 miles (710 kilometers) away in Stanfield, Arizona, Thomas J. Bopp also spied it. Following confirming observations and the calculation of an orbit by Brian Marsden, Comet Hale-Bopp (C/1995 O1) was born.

Incredibly, at its discovery, the comet was a staggering 700 million miles (1.1 billion km) away — between the orbits of Jupiter and Saturn. Although at this distance most comets would appear as tiny specks, Hale-Bopp already showed a coma. Scottish-Australian astronomer Robert McNaught, at the Anglo-Australian Telescope at Siding Spring, found a 1993 image of the comet showing a coma at the great distance of 1.2 billion miles (2 billion km) between the orbits of Saturn and Uranus. At that distance, Halley's Comet would have been more than 100 times fainter than Hale-Bopp.

Astronomers, professional and amateur, would be able to view Hale-Bopp for a long time before it moved into the inner solar system. Scientists were immediately excited by the fact that Comet Hale-Bopp was likely to brighten substantially, reaching a



Comet Hale-Bopp (C/1995 O1) wowed observers in 1996 and 1997, becoming the most observed comet in the 20th century. BILL AND SALLY FLETCHER

perihelion distance of 85 million miles (137 million km) April 1, 1997, and swinging past Earth at a distance of 122 million miles (197 million km) March 22.

No one knew it quite yet at discovery, but Hale-Bopp was destined to become the brightest comet of its era and was perhaps the most widely observed comet in history, given the huge numbers of the general public who looked at it with unaided eyes, binoculars, or telescopes. Calculations showed the comet would peak shining brighter than any star in the night sky except for Sirius, the brightest star. Starting May 20, 1996, Hale-Bopp would remain visible to the naked eye for 569 days — more than 18½ months, the longest period of unaided visibility of a known comet. That record would double the previous nine-month record set by the Great Comet of 1811.

Now the stage was set for Comet Hale-Bopp to put on its spectacular show. The incredible display of this amazingly bright comet and its prominently fanned gas tail awed millions of people across the globe, and the media coverage of the comet was enormous. The comet became one of the most beloved of all time. Comet Hale-Bopp became one of history's greatest comets, a path we all certainly hope Comet ISON will follow.

Yours truly,



David J. Eicher
Editor

Astronomy

Editor David J. Eicher
Art Director LuAnn Williams Belter

EDITORIAL STAFF
Managing Editor Ronald Kovach
Senior Editors Michael E. Bakich, Richard Talcott
Associate Editors Liz Kruesi, Sarah Scoles
Assistant Editor Karri Ferron
Editorial Associate Valerie Penton

ART STAFF
Senior Graphic Designer Chuck Braasch
Illustrator Roen Kelly
Production Coordinator Jodi Jeranek

CONTRIBUTING EDITORS
Bob Berman, Glenn F. Chaple, Jr., Martin George, Tony Hallas, Phil Harrington, Ray Jayawardhana, David H. Levy, Alister Ling, Steve Nadis, Stephen James O'Meara, Tom Polakis, Martin Ratcliffe, Mike D. Reynolds, Sheldon Reynolds, John Shibley, Raymond Shubinski

EDITORIAL ADVISORY BOARD
Buzz Aldrin, Marcia Bartusiak, Timothy Ferris, Alex Filippenko, Adam Frank, John S. Gallagher III, Daniel W. E. Green, William K. Hartmann, Paul Hodge, Anne L. Kinney, Edward Kolb, Stephen P. Maran, Brian May, S. Alan Stern, James Trefil

Kalmbach Publishing Co.

President Charles R. Croft
Vice President, Editorial, Publisher Kevin P. Keefe
Vice President, Advertising Scott Stollberg
Vice President, Marketing Daniel R. Lance
Corporate Art Director Maureen M. Schimmel
Managing Art Director Michael Soliday
Production Manager Helene Tsigistras
Corporate Circulation Director Michael Barbee
Group Circulation Manager Ken Meisinger
Single Copy Sales Director Jerry Burstein
Circulation Specialist Sarah Zemplinski

ADVERTISING DEPARTMENT
(888) 558-1544
Advertising Director Scott Bong
Advertising Sales Manager Jeff Felbab
Advertising Sales Representative
Ken Kozerski, kkozerski@kalmbach.com
Ad Services Representative
Christa Burbank, ads@astronomy.com

RETAIL TRADE ORDERS AND INQUIRIES
Selling *Astronomy* magazine or products in your store:
Phone (800) 558-1544, Press 3
Outside U.S. and Canada (262) 796-8776, ext. 818
Fax (262) 798-6592
Email tss@kalmbach.com
Website www.Retailers.Kalmbach.com

CUSTOMER SALES AND SERVICE
Phone (800) 533-6644; **Fax** (262) 796-1615
customerservice@kalmbach.com

SPECIAL EMAIL ADDRESSES
Ad Sales adsales@astronomy.com
Ask Astro askastro@astronomy.com
Books books@astronomy.com
Letters letters@astronomy.com
Products products@astronomy.com
Reader Gallery readergallery@astronomy.com

Editorial phone: (262) 796-8776; advertising: (888) 558-1544; customer service & sales: (800) 533-6644; outside the U.S. and Canada: (262) 796-8776, ext. 421, Monday through Friday, 8:30 A.M. to 4:30 P.M. CT, Fax: (262) 796-1615; Email: customerservice@kalmbach.com. Please include your name, mailing address, and telephone number with any correspondence.

Copyright © 2013 Kalmbach Publishing Co., all rights reserved. This publication may not be reproduced in any form without permission.
Printed in the U.S.A. Allow 6 to 8 weeks for new subscriptions and address changes. Subscription rate: single copy: $5.99; 1 year $42.95, 2 years (24 issues) $79.95, 3 years (36 issues) $114.95; Canadian price: 1 year $50.95, 2 years $95.95, 3 years $138.95 (Canadian price includes additional postage and GST, payable in U.S. funds.) International price: 1 year $58.95, 2 years $111.95, 3 years $162.95 (International price includes additional postage, payable in U.S. funds.) Expedited Delivery Service Surcharges: Domestic 1st Class $30 per year, Canadian air $30 per year, International air, $60 per year. BN 12271 3209 RT. Not responsible for unsolicited materials.

Follow *Astronomy*
www.twitter.com/AstronomyMag
www.facebook.com/AstronomyMagazine

Alliance for Audited Media
KALMBACH PUBLISHING CO.
Please Recycle This Magazine

ORION®

Since 1975

EVERYTHING FOR THE AMATEUR ASTRONOMER



Orion® 8" f/3.9 Newtonian Astrograph Reflector
#8297 **$499.99**



Set of Orion® Q70™ Eyepieces: 26, 32, 38mm
#24708 **$249.99**



Big-aperture exhilaration and state-of-the-art GoTo electronics

Orion® SkyQuest™ XX16g GoTo Truss Tube Dobsonian
#8968 **$3,599.99**



Orion® UltraView™ 10x50 Wide-Angle Binoculars
#9351 **$179.99**



Orion® 1.25" SkyGlow™ Broadband Filter
#5660 **$79.99**



Orion® EZ Finder™ Deluxe II Reflex Sight
#7231 **$79.99**



Orion® Awesome AutoGuider Refractor Package
#24770 **$399.99**



Orion® StarShoot™ Solar System Color Camera IV
#52175 **$99.99**



Orion® SkyScanner™ 100mm TableTop Reflector
#10012 **$119.99**



Orion® 20mm Illuminated Centering Eyepiece
#8239 **$99.99**





Orion® SteadyPix™ Universal Smartphone Adapter
#5693 **$69.99**



Orion® Thin Off-Axis Guider for Astrophotography
#5531 **$149.99**

Orion® StarBlast™ AutoTracker Altazimuth Mount
#8975 **$199.99**



(camera not included



Orion® Giant View™ 25x100 Astronomy Binoculars
#9326 **$349.99**

Orion® SkyQuest™ XT8 PLUS Dobsonian
#8974 **$499.99**



Orion® StarShoot™ G3 Deep Space Mono Imaging Camera
#53083 **$399.99**



Orion® Dual Finder Scope Mounting Bracket
#10145 **$49.99**

Orders: (800) 447-1001
Customer Service: (800) 676-1343
Suggested retail prices subject to change.

OrionTelescopes.com

Check out the Orion page on Facebook
www.facebook.com/oriontelescopes

THE DEFINITIVE GUIDE TO Comet ISON

***The Great Comet of 2013* gets you ready for the spectacular appearance of what could be the century's brightest comet!**

Trust the experts at *Astronomy* magazine to bring you Comet ISON's complete story, including:

OPTIMAL VIEWING PERIODS: Discover the ideal time for your location

OBSERVING TIPS: Get day-by-day info for October through January

EQUIPMENT ADVICE: Find out what's best to view the comet

IMAGING HOW-TOs: Learn how to successfully capture Comet ISON

And **MUCH MORE!**



ORDER NOW to **SAVE $1** and receive **FREE SHIPPING** on this new special issue!

www.Astronomy.com/CometISON
or call **1-800-533-6644**

Monday – Friday, 8:30 a.m. – 4:30 p.m. CDT. Outside the United States and Canada call 262-796-8776, ext. 661. Please have your credit card ready.

***The Great Comet of 2013* arrives in early October 2013.**

WorldMags.net

Astronomy magazine

P19556 Background: Comet McNaught (C/2006 P1) by Martin Moline A3BAA7

QG QUANTUM GRAVITY

EVERYTHING YOU NEED TO KNOW ABOUT THE UNIVERSE THIS MONTH . . .

HOT BYTES >>

TRENDING TO THE TOP



SUN-SYSTEM TAIL
Researchers reported July 10 that the Sun's protective magnetic bubble, the heliosphere, has a trailing "heliotail" that is flatter and broader than expected.



GUSHING GAS
Data from NASA's Spitzer telescope show that Comet ISON emitted 2.2 million pounds (1.0 million kg) of carbon dioxide gas per day in June.

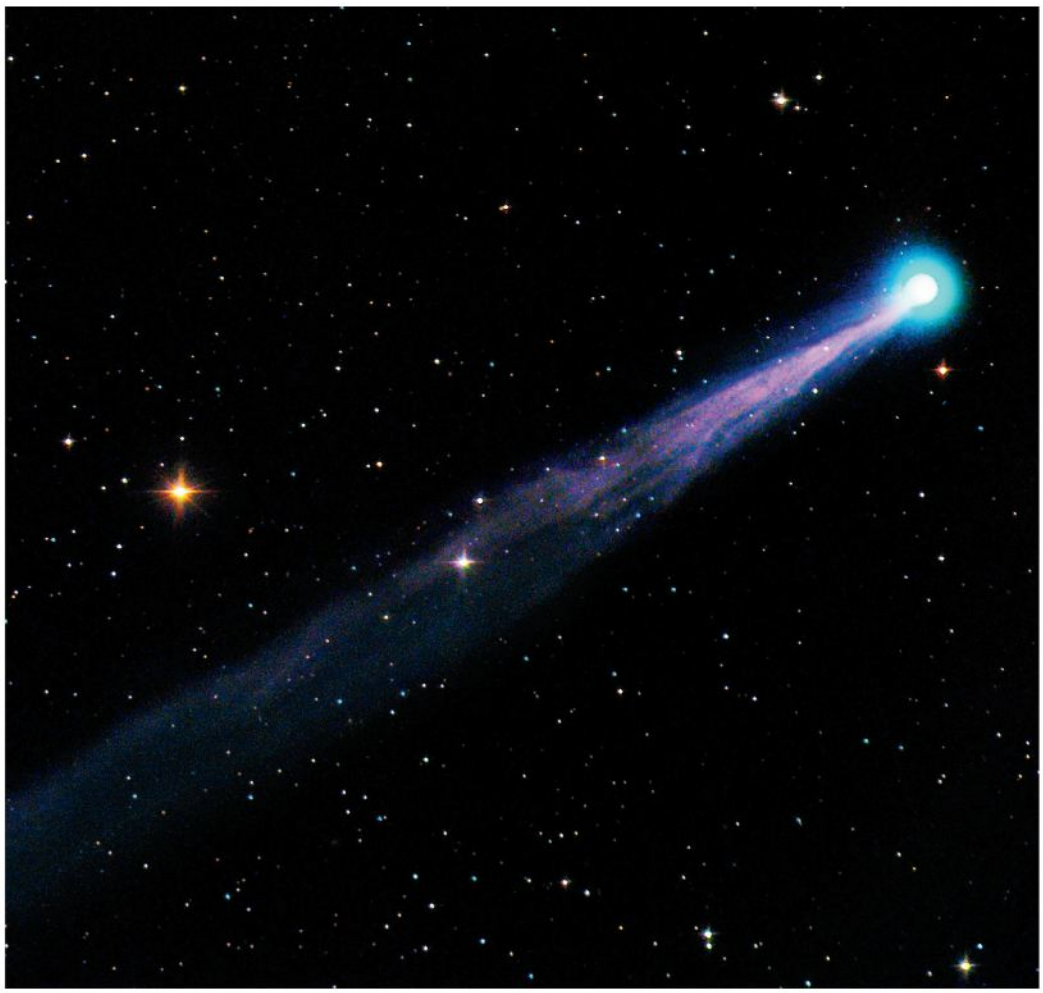


HABITABLE HOSTS?
Binary stars might host habitable planets if they orbit each other with a period that synchronized to 15 to 30 days in the suns' first billion years.

CONTEST

Give us your best shot

Whether Comet ISON is a once-in-a-lifetime event, a great performer, or a run-of-the-mill comet, your picture of it could win a $2,500 prize.



GERALD RHEMANN (COMET SWAN); NASA'S GODDARD SPACE FLIGHT CENTER (SUN-SYSTEM TAIL); NASA/JPL-CALTECH/JHUAPL/UCF (GUSHING GAS); LYNETTE COOK (HABITABLE HOSTS?)

On September 30, 2006, astroimager Gerald Rhemann captured Comet SWAN (C/2006 M4). Can you take a better shot of Comet ISON?

Comet ISON looks to be the most publicized comet of our lifetimes — and perhaps the most photographed. Because so many people are planning to snap pictures of it, the National Science Foundation's Division of Astronomical Sciences, *Discover* magazine, and *Astronomy* are co-sponsoring the Comet ISON Photo Contest.

The contest is open to amateur and professional photographers worldwide. You can submit images online at www.nsf.gov/comet beginning October 15, 2013, through January 15, 2014.

Judges will consider images in three categories: 1) **Cameras and tripods** without the use of tracking or telescopes; 2) **Piggyback cameras** riding atop a telescope or motorized mount; 3) **Through-the-scope** images where the telescope acts as the camera's lens.

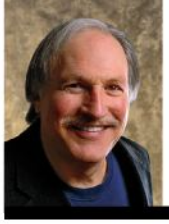
First prize in each category is $2,500. Second prize is $1,000. In addition to the six prize winners, website visitors will choose an additional "People's Choice" award worth $1,500.

Winners will be notified before the public announcement is made in April 2014. Winning images will appear in print in *Astronomy* and online at Astronomy.com, Discover.com, and on the NSF website at www.nsf.gov/comet.

For complete rules, eligibility, judging criteria, frequently asked questions, and to learn how to submit your images, go to www.Astronomy.com/ISONphotos.

Your picture of Comet ISON may turn out to be a once-in-a-lifetime image. **— Michael E. Bakich**

WorldMags.net



STRANGE**UNIVERSE**

BY BOB BERMAN

Night sweats

Astronomers must overcome the ancient human fear of darkness.

Autumn brings ever-expanding night. For many, this is not pleasant. Hallowe'en unites classic darkness terrors with deliberate spookiness. And November in most of the United States and Canada is when suddenly bare, twisted branches and stronger gusts create a mood of icy menace. Outdoors, life's colors and scents vanish. Even the birds pack it up and flee.

Most astronomers welcome these expanding eyepiece opportunities — especially when our sister galaxy, Andromeda, is overhead and we get our first peek at the returning brilliance of Orion and his friends. But even backyard stargazers sometimes look over their shoulders when cold winds howl. It can be creepy out there.

We glorify space travel and the notion of human colonies on other worlds. But astronauts will tell you: The starry realm is not benign. Death lurks beyond the crew compartment's metal walls.

An unprotected person accidentally hurled out a spaceship's airlock, that common sci-fi scene, would stay conscious for no more than 20 seconds. Composed mostly of water, a human body would quickly revert to the universe's commonest form of H_2O — a block of ice. If subsequently struck by a meteoroid, the body would shatter into pieces, perhaps dividing itself along internal fault structures defined by organs. If the experience occurred near Jupiter, radiation would sterilize all living tissue. Near white dwarfs or neutron stars, tidal forces would rip a skeleton to pieces.

In Earth's vicinity, the side of the unprotected astronaut's body facing sunward would rapidly heat like a microwave to some 250° Fahrenheit (120° Celsius), above water's boiling point. Searing solar ultraviolet rays — including the fearsome UVC never experienced on Earth's surface — would deliver a painful burn in 20 seconds. A three-minute exposure would cook skin to carbon. Meanwhile, being in a vacuum would nullify one's health insurance. The pressure differential would force body gases outward; eardrums and eyeballs would pop.

We are creatures of Earth. We carry our planet inside us, fashioned as we are of terrestrial components like oxygen, which alone constitutes 65 percent of our bodies by mass. The more typical stuff of the cosmos — hydrogen and helium — offers no nourishment or support on its own. Fear of the sky thus has a rational basis.

EVEN BACKYARD STARGAZERS SOMETIMES LOOK OVER THEIR SHOULDERS WHEN COLD WINDS HOWL.

For some reason, children below the age of 2 are rarely afraid of the dark. But they soon make up for this slow start, since it eventually afflicts a majority of kids. If severe enough, a fear is a "phobia," and if the enemy is darkness, the condition is variously called nyctophobia (from the Greek word for night), achluophobia, scotophobia, or lygophobia. The only phobia with four different names, it afflicts 11 percent of U.S. adults, according to the National Institute of Mental Health. It edges out acrophobia (fear of heights) but, in prevalence, ranks below fear of public speaking (glossophobia), fear of death (necrophobia), and fear of spiders (arachnophobia). I'm not sure where fear of dropping an expensive eyepiece fits in.

For kids, it's not the actual dark that scares them, but its unseen terrors. Ghosts don't emerge until nightfall, and that shirt slung over a chair surrenders its monster shape only with the dawn. Even many non-phobic adults retain a lifelong nocturnal discomfort. The cause? Well, most ancient cultures feared darkness because of tigers and such, since these predators often boast superior low-light vision. They have the edge after nightfall.

The strange netherworld of dreams doesn't help. Despite modern "dream labs" and sleep experiments, the little we know is more mystifying than clarifying. No one can explain why dreams get longer as night passes or why early dreams relate to recent events while later ones tend to be more surreal and mysterious in content.

Beyond the psychological explanations, might night sweats stem from actual dangers posed by the starry canopy? Do we harbor genetic memories of celestial cataclysms like meteoric destruction? Probably not. The sky has rarely been a source of injury. Only one person in recorded history was definitely struck by a meteorite, and that was by day. In Sylacauga, Alabama, Ann Hodges suffered a bruised thigh in 1954 after a chondrite came through her roof and ricocheted off a radio. Many others (in 1992 and in 1996, for example) have had close calls when meteorites plowed into their lawns just as they walked by — again, all by day.

So, away from city lights, the nocturnal realm is generally friendly, with many rural meadows filled with nothing more menacing than garden-destroying deer. A nightly stroll under benignly wheeling stars is a low-risk activity. Indeed, we astronomers should perhaps quote Shakespeare. It was he, in *Romeo and Juliet*, who foresaw a time when "all the world will be in love with night. And pay no worship to the garish sun."

So let the darkness blossom. Nyctophobia begone!

Contact me about my strange universe by visiting **http://skymanbob.com.**

FROM OUR INBOX

In remembrance of a loyal reader

My late husband was a charter subscriber to *Astronomy* when it was first published. His name was Howard Duncan, and his dream was to afford a Meade telescope.

He passed away in 2000, without ever realizing that dream, but he looked forward to *Astronomy* magazine every month. I haven't been able to afford the subscription, but I am always in awe of the refinement of the telescopes and the clarity of the photos that await the seekers in the universe.

Thank you for giving my late husband so much to look forward to! **— Doris McClellan,** Henderson, Nevada

We welcome your comments at Astronomy *Letters, P. O. Box 1612, Waukesha, WI 53187; or email to letters@astronomy.com. Please include your name, city, state, and country. Letters may be edited for space and clarity.*

QG QUANTUM GRAVITY

BROWSE THE "STRANGE UNIVERSE" ARCHIVE AT **www.Astronomy.com/Berman.**

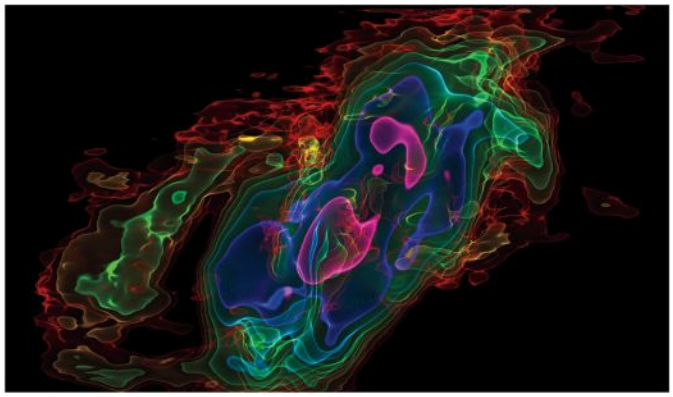


A galactic incubator

Collisions between galaxies are more of the cosmic norm than an aberration, but few such interactions have the visual appeal of the pair known collectively as Arp 142. In this celestial impact, tidal forces unleashed by the gravity of elliptical galaxy NGC 2937 (bottom) distort the previously normal spiral NGC 2936 (just above it). The spiral's arms and dark dust lanes now splay haphazardly across that galaxy's disturbed disk, while bright blue knots trace the sites of ongoing star formation. Amateur astronomers have dubbed Arp 142 "the Penguin" because it resembles the flightless bird (NGC 2936) safeguarding an egg (NGC 2937). NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

WorldMags.net

ENERGETIC EVENT. For the first time, the Chandra and XMM-Newton telescopes witnessed a planet passing in front of its parent star and blocking its X-rays, a result published in the August 10 issue of *The Astrophysical Journal*.



STARBURST STARVATION. By mapping the distribution of cold carbon monoxide gas in NGC 253 (from less intense emissions in red to brighter radiation in pink), astronomers were able to identify the gas emerging from the galaxy's central star-forming region. Such an outflow could hinder future star formation. ALMA (ESO/NAOJ/NRAO)/E. ROSOLOWSKY

ALMA ANSWERS KEY GALAXY EVOLUTION QUESTION

Astronomers continually seek observations that will support their leading models of galaxy evolution and answer remaining questions. Based on the lack of extremely massive galaxies found in the universe, they know something must hinder a galaxy's star production to keep it from continuing to grow at a vigorous rate. The models suggest ongoing star formation could be the cause as the extreme stellar winds and ultimate explosions of massive stars fling molecular gas — the fuel for future suns — out of a galaxy. But astronomers lacked observational proof to support the theory — until now.

Using the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile, astronomers gained their first direct evidence of molecular gas streaming away from an active region of star formation in the heart of the Sculptor Galaxy (NGC 253).

"With ALMA's superb resolution and sensitivity, we can clearly see for the first time massive concentrations of cold gas being jettisoned by expanding shells of intense pressure created by young stars," says Alberto Bolatto of the University of Maryland, College Park, lead author of the NGC 253 study published July 25 in *Nature*. "The amount of gas we measure gives us very good evidence that some growing galaxies spew out more gas than they take in."

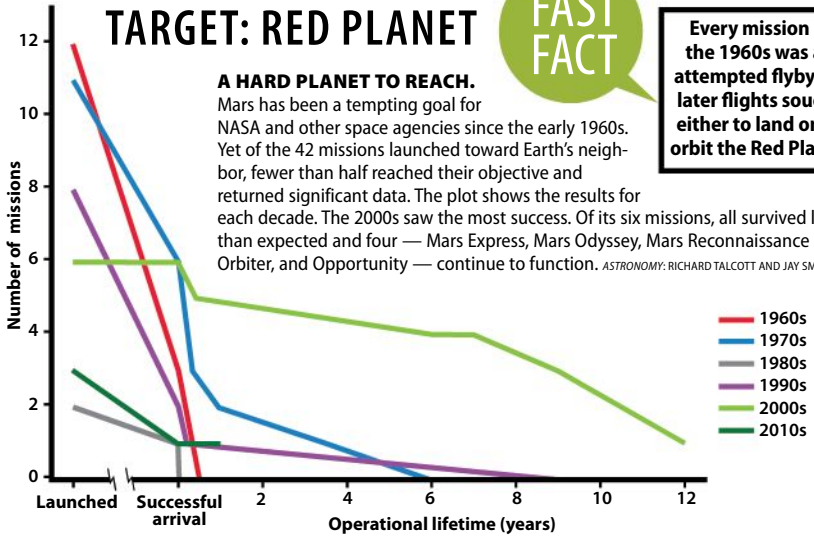
In fact, Bolatto and his team determined that the total mass-outflow rate is more than three times the measured star-formation rate. At that pace, NGC 253 would run out of gas in as few as 60 million years. Still, future ALMA observations are needed to determine if the gas completely escapes the Sculptor Galaxy to starve future star formation or if it lingers in NGC 253's halo and eventually falls back in. **— Karri Ferron**

TARGET: RED PLANET

FAST FACT

Every mission in the 1960s was an attempted flyby; all later flights sought either to land on or orbit the Red Planet.

A HARD PLANET TO REACH. Mars has been a tempting goal for NASA and other space agencies since the early 1960s. Yet of the 42 missions launched toward Earth's neighbor, fewer than half reached their objective and returned significant data. The plot shows the results for each decade. The 2000s saw the most success. Of its six missions, all survived longer than expected and four — Mars Express, Mars Odyssey, Mars Reconnaissance Orbiter, and Opportunity — continue to function. *ASTRONOMY*: RICHARD TALCOTT AND JAY SMITH



BRIEFCASE

ORBITS AND AGES

Globular cluster 47 Tucanae contains two separate populations of stars, say astronomers in the July 1 issue of *The Astrophysical Journal Letters*. One holds younger, bluer stars with elliptical orbits concentrated near the core; members of the other are about 100 million years older, redder, and have circular orbits farther out from the cluster's center.

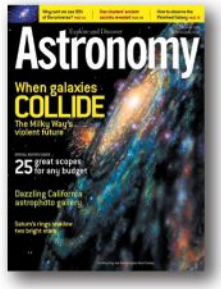
QUASAR SEARCHLIGHTS

Two teams of scientists used two different quasars — the extremely bright centers of active galaxies — as backlights to study unrelated galaxies closer to Earth. A July 5 *Science* paper describes researchers' observations of gas outside a galaxy moving inward to feed star formation. In an August 21 *Monthly Notices of the Royal Astronomical Society* article, astronomers report finding that gas at a galaxy's center is just as rich in oxygen as gas in its outer regions. Both galaxies studied existed some 11 billion years ago.

MAGNETIC MOVEMENT

The Sun's visible surface has a temperature of about 5800 kelvins, while its outer atmosphere is at least 1 million K; what heats this corona is a long-standing question in astronomy. Solar scientists from Columbia University announced July 9 at the meeting of the Solar Physics Division of the American Astronomical Society in Bozeman, Montana, that their recent observations suggest magnetic "Alfvén" waves under the Sun's surface carry energy beyond the surface and deposit it into the corona. **— Liz Kruesi**





25 years ago in *Astronomy*

In the November 1988 issue of *Astronomy*, Gerrit Verschuur wrote "A New 'Yardstick' for the Universe" about an early gravitational lens discovery. As he described lensing, "If a distant galaxy lies directly behind a massive galaxy closer to home, the light from the distant galaxy should be bent and refocused by the interloper."

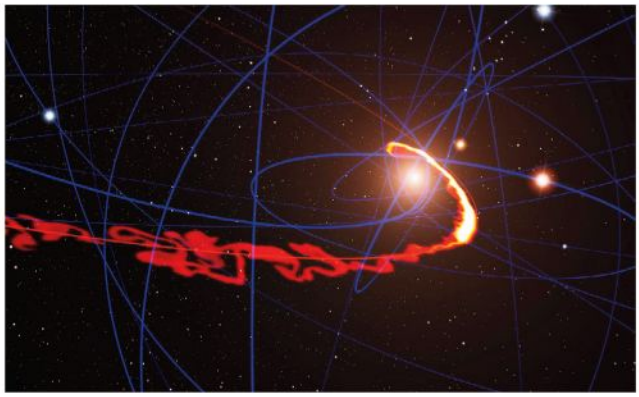
The discoverer, Jacqueline Hewitt of the Haystack Observatory, hoped lensing would allow scientists to quantify dark matter. Scientists would not discover that dark energy is causing the universe's expansion to accelerate for another 10 years.

10 years ago in *Astronomy*

In the November 2003 issue of *Astronomy*, Michael S. Turner composed "Absurd universe" about how little of the cosmos is "regular matter." He based his write-up on the first results from the Wilkinson Microwave Anisotropy Probe (WMAP): 0.5 percent regular matter, 33 percent dark matter, and 66 percent dark energy.

In March 2013, WMAP's sensitive successor, Planck, released its first results, and scientists now estimate that the universe is a little bit less absurd, containing 4.9 percent regular matter, 26.8 percent dark matter, and 68.3 percent dark energy. **— Sarah Scoles**

WorldMags.net



CLOSE CALL. The cloud of gas and dust called G2 has begun its close encounter with the black hole at the center of the Milky Way. As the two continue to interact, the black hole's gravity will stretch G2 dramatically, as shown in this still from a simulation. ESO/S. GILLESSEN/MPE/MARC SCHARTMANN

G2 gas cloud stretched as it rounds Milky Way's black hole

A cloud of dust and gas with three times Earth's mass is making its closest approach to the black hole at the center of the Milky Way, the supermassive Sagittarius A*, according to a paper in the February 1 issue of *The Astrophysical Journal*. The cloud, called G2, will not fall into the black hole, but it will come so close that extreme gravity will stretch it out in a process termed "spaghettification."

Already, the head of the cloud is pulling away from the tail. The orbit is taking it around the other side of the black hole at more than 6 million mph (10 million km/h). The tail soon will follow, as gravity renders G2 longer and thinner with each passing second.

This chance meeting between G2 and Sagittarius A* is a rare opportunity for astronomers to get a peek at our surprisingly calm galactic center. Although the black hole is 4 million times as massive as the Sun, no one has ever seen it eat. Black holes are as their names sound — black, hole-like — but material that approaches them heats up, speeds up, and then emits radiation that telescopes can see, as G2 is now doing.

Luckily for astronomers, the cloud and its encounter will be visible for a while. "The cloud is so stretched that the close approach is not a single event," says G2's co-discoverer Stefan Gillessen of the Max Planck Institute for Extraterrestrial Physics in Garching, Germany, "but rather a process that extends over a period of at least one year." **— S. S.**

QUICK TAKES

SWITCH HITTER

Star Tau Boötis' magnetic field flips once a year, 11 times more often than the Sun's, according to a presentation July 4 at the National Astronomy Meeting of the Royal Astronomical Society.

IN THE CLOUDS

Habitable zones around red dwarfs expand if the planets have clouds, which reflect radiation and heat to space, says a paper in the July 10 issue of *The Astrophysical Journal Letters*.

MOON MONIKERS

On July 2, the International Astronomical Union officially recognized new names for Pluto's two smallest moons. P4 and P5 have become Kerberos and Styx, respectively.

EXTREME MAKEOVER

Results from NASA's MESSENGER mission, published July 4 in *Nature*, show that Mercury received a face-lift 4.0–4.1 billion years ago, when volcanoes resurfaced the planet.

ROCKET SCIENTISTS

The European Space Agency announced July 9 that British company Thales will be the prime contractor for Euclid, a 2020 mission to study dark matter and dark energy.

BIG BABY

Scientists found a still-forming star already 500 times as massive as the Sun — the largest known in our galaxy, says a paper forthcoming in *Astronomy & Astrophysics*. **— S. S.**



NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE

Cassini catches Earth on camera

SAY CHEESE. NASA's Cassini spacecraft snapped this photo of Earth as seen from Saturn's rings. The image shows our planet as it appears from 898 million miles (1.44 billion kilometers) away: a pale blue dot dwarfed by Saturn's dark side and its nearby immense rings. This image is one of 323 that make up a complete three-color mosaic of the ring system. In NASA's July 22 release of the image, the agency stated that this was "the first time that inhabitants of Earth knew in advance that their planet was being imaged." **— S. S.**

Telescopes.net

SIA SCIENCE, IMAGING, & ASTRONOMY EXPO

Save the Date! October 19th

Being held at Pierce College.
We have many manufacturers with thousands of dollars of giveaways and raffles. Come for the food and stay for the conferences with world-renowned speakers and amazing prizes and sales.

Proud Sponsors
Woodland Hills Camera & Telescopes and Pierce College

RAFFLE TICKETS AVAILABLE
Grand Prize Drawings to the Lucky Winners

Meade 10" LX 600 Advanced coma free telescope
Explore Scientific ED127CF and 100° eyepieces

And many more prizes throughout the day

SBIG ASTRONOMICAL INSTRUMENTS
STi
STARTING FROM: $495.00

MEADE
LX850
NEW PRODUCT
NEW LOWER PRICE!

CORONADO
Rich View SolarMax II

CELESTRON
CGE Pro 1400 HD

APOGEE IMAGING • ASA • ATIK • CANON • CELESTRON • CORONADO • EXPLORE SCIENTIFIC • FARPOINT • FLI • JMI • KENDRICK • LUMENERA • LUMICON • MEADE • MOONLITE • OFFICINA STELLARE ORION • QSI • SBIG • SKY-WATCHER USA • SOFTWARE BISQUE • STARLIGHT EXPRESS • TAKAHASHI • TELE VUE • THE IMAGING SOURCE • VIXEN PLANEWAVE

Woodland Hills Telescopes
5348 Topanga Canyon Blvd.
Woodland Hills, CA 91364
Mon-Sat: 9am-6pm (PST)
Toll Free: (888) 427-8766
Local: (818) 347-2270
Fax: (818) 992-4486



OBSERVING**BASICS**

BY GLENN CHAPLE

Laser pointer safety

Know how to properly use this helpful star party tool to avoid harming others.



When not used properly, geen laser pointers turned skyward can flood an airplane or helicopter cockpit with blinding light. COURTESY LASD

For many years, one of the biggest stumbling blocks I faced at star parties was the confusion that arose whenever I tried to show attendees the locations of notable stars and constellations or the whereabouts of the current telescopic target. Except for those standing directly behind me, few, if any, could see where I was pointing.

The laser pointer came to the rescue. Here is a small, inexpensive device whose bright green beam, when directed skyward, illuminates minute dust particles in the air. The result is what looks like a *Star Wars* light saber that seems to stretch all the way to the stars themselves. No sooner did I learn of this valuable tool than I ordered one for myself.

What a difference it made at star parties! I could now point out objects in the sky to an audience of dozens, confident that all eyes were directed exactly where I wanted. Next to the telescope, a laser pointer has become my most-used star party accessory.

As with any innovation, though, there is a downside. In the right hands, a laser pointer is a useful device; in the wrong hands, it becomes at the very least a public nuisance, at worst a dangerous weapon.

The most common negative use comes from seemingly harmless pranks by those who have little or no knowledge of the power of even the smallest laser pointers. They flash them at each other, at neighborhood houses, passing vehicles, even screens at movie theaters.

More serious is the purposeful misuse of laser pointers at outdoor concerts and athletic events. Last year, a visibly angered Kanye West interrupted a performance to confront an audience member who had aimed a green laser at him. A fan was arrested at an August 2012 Cardinals–Giants baseball game after shining his laser at a Giants pitcher. The problem is global, with spectators flashing laser pointers at players during international soccer matches.

Perhaps the most dangerous misuse of laser pointers is the deliberate targeting of moving vehicles and aircraft. Last April, I received an email from Reserve Deputy Robin Price of the Los Angeles County Sheriff's Department. Laser hits on police cruisers and aircraft have become a serious problem in L.A., recently reaching epidemic proportions. Knowing that laser pointers are popular with amateur astronomers, he asked me to alert the readers of *Astronomy* to the crisis and refer them to the department's YouTube video "Laser Strike" (http://youtu.be/2RrR0Tc1w90).

When I first heard of reports that a laser pointer could temporarily blind operators of moving vehicles or aircraft, I was skeptical. How could the beam enter their quarter-inch-wide pupil and remain there long enough to cause visual impairment? "Laser Strike" set me straight. The beam doesn't have to hit the pilot or driver directly in the eye. A simple glance off a windshield creates a blinding flash that floods the vehicle or cockpit. While it's true that some of these hits are accidental, many are intentional. Criminals shine green laser pointers at police cruisers and helicopters as a means of incapacitating the occupants long enough to make an escape.

Amateur astronomers can't alone stop the "invasion of the green laser," but we can help by making sure we're not part of the problem. Star parties should not be set up within 2 miles (3 kilometers) of an airport, and we should never let any attendee try our laser pointers. Because even the most knowledgeable skygazer has mistaken the landing light of an approaching airliner for a bright planet or star (c'mon, you *know* you've done it!), the website Laser Pointer Safety (www.laserpointersafety.com) advises us to "NEVER point directly at a dim or unknown 'star.' Instead, move in a circular motion around the object. When doing the circular motion, or when 'drawing out' a constellation, keep the beam moving and keep it away from any stars. The 'stars' may be aircraft." As well as allowing us to demonstrate sensible use of laser pointers, a star party is a perfect forum for enlightening the community about the hazards inherent in the misuse of these seemingly harmless instruments.

Besides educating the public about the problem, we need to report any illegal use of laser pointers. Laser Pointer Safety and the Federal Aviation Administration's Laser Safety Initiative (www.faa.gov/about/initiatives/lasers) provide guidelines for reporting such abuse. Both sites, plus the "Laser Strike" video clip, are must-see sources for anyone seeking information on laser pointer safety.

Questions, comments, or suggestions? Email me at gchaple@hotmail.com. Next month: my December 2012 "Prime 9" sky objects revisited. Clear skies!

FROM OUR INBOX

Cosmos induces awe and horror

Your story about Carl Sagan brought back memories. I am a great grandmother now, but I remember watching each episode of *Cosmos*. When Sagan explained how we are all made of star stuff, I got goose bumps. It was an idea I had not heard before.

I read the book *Cosmos*, too, and it sent me off in multiple directions of study. It really opened the universe to me and changed the way I thought about everything. I have all of Sagan's books and have read them more than once. He left us way too soon. **— Ann Freeman,** Cheyenne, Wyoming

I enjoyed the article about Carl Sagan and the television program *Cosmos*. However, I noted with horror that the gold plaques sent along with the Pioneer probes include Pluto as a planet. Does NASA have any plans to send a correction?
— Tom Dempsey, Chadds Ford, Pennsylvania

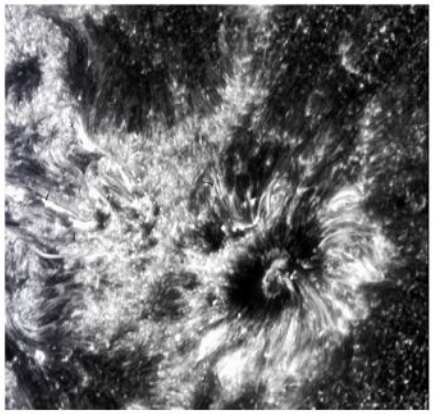
BROWSE THE "OBSERVING BASICS" ARCHIVE AT **www.Astronomy.com/Chaple.**

WorldMags.net

ASTRONEWS

FAST FACT

NASA's IRIS probe is 7 feet long (2.1 meters), and its solar panels stretch 12 feet (3.7m).



SOLAR STUDY. NASA's newest telescope to observe the Sun captured its first image July 17, revealing features as small as 150 miles (240 kilometers) across. NASA/IRIS

Solar probe IRIS sees first light

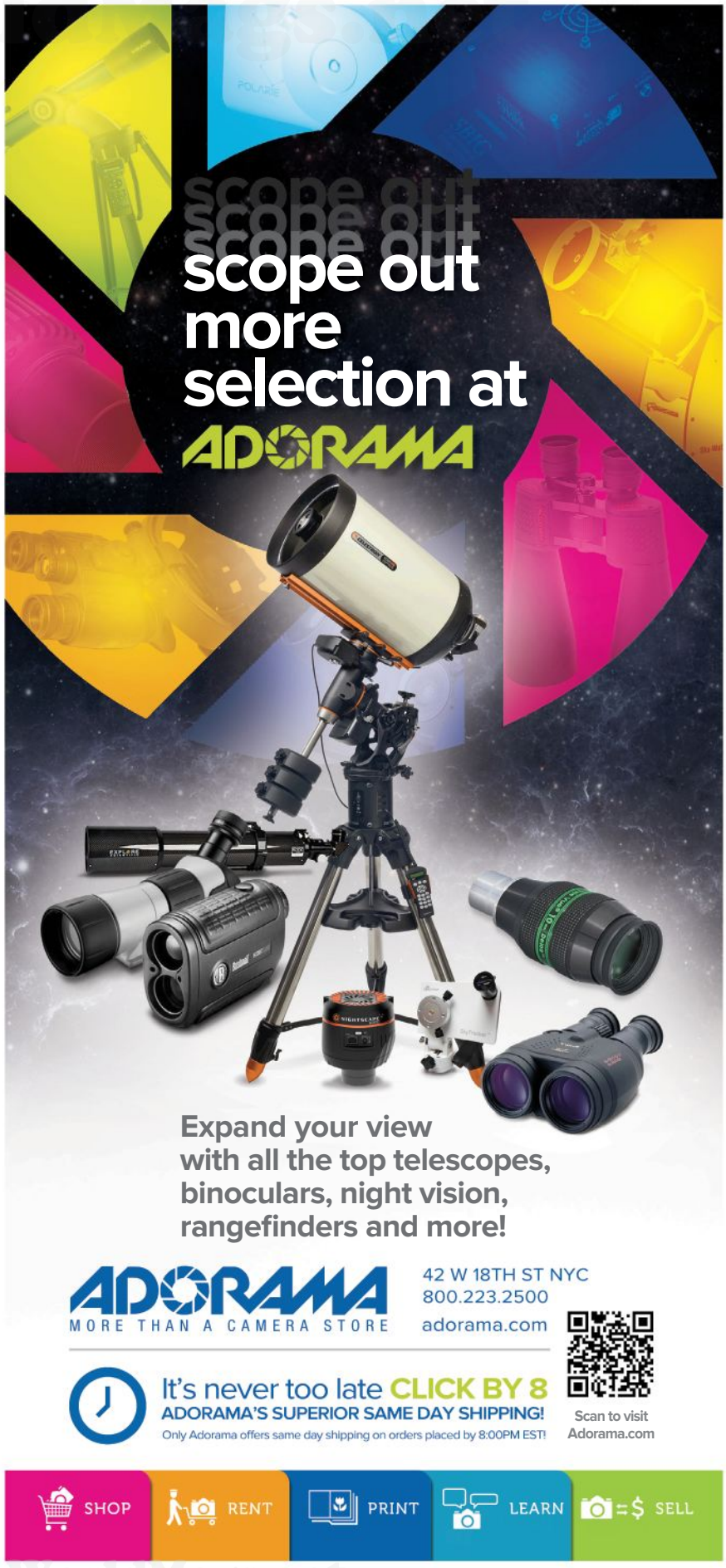
The Interface Region Imaging Spectrograph (IRIS) took its first look at the Sun on July 17. This NASA spacecraft launched June 27 with the goal of tracing the flow of energy and material across the Sun's surface and into its atmosphere. Scientists don't yet understand what heats the Sun's upper atmosphere, called the corona, to its extreme temperature of 1 million kelvins (1.8 million degrees Fahrenheit) or more, whereas the solar surface is some 5800 K (9940° F).

IRIS' instrument has two purposes: It's an ultraviolet imager as well as a spectrometer, which breaks apart the Sun's light into its constituent wavelengths. The instrument captures a new picture every five to 10 seconds and a new spectrum every one to two seconds. The telescope observes material at temperatures between about 5000 K and 65,000 K (8500° F and 116,000° F), and its spectroscope captures information for material as hot as 10 million K (18 million degrees F).

The spacecraft's telescope is just 8 inches (20 centimeters) in diameter and can capture details as small as 150 miles (240 kilometers) across on the Sun. Scientists will incorporate the data from IRIS into computer simulations to learn how energy travels through the Sun's atmosphere. **— L. K.**

531,261

The number of detections of 372,728 X-ray-emitting objects in the newest "XMM-Newton Serendipitous Source Catalogue," released July 23.



ASTRO**CONFIDENTIAL** BY KARRI FERRON

WHAT ARE WE LEARNING ABOUT DWARF GALAXIES AND DARK MATTER?

James Bullock Professor in the Department of Physics & Astronomy at the University of California, Irvine

Most galaxies in the universe are not blazing giants like our Milky Way; they're dim dwarfs of less grand dimensions. The tiniest galaxies known, the ultra-faint dwarf spheroidals, contain only a few thousand stars. While the stars of the Milky Way are effectively uncountable, you could count the stars in an ultra-faint dwarf in minutes.

Ten years ago, we had no idea that galaxies could be so small. But thanks to modern sky surveys, we've discovered dozens of ultra-faint dwarfs orbiting the Milky Way and its large companion, the Andromeda Galaxy. These tiny galaxies likely fill the cosmic landscape beyond our view, outnumbering giant galaxies a hundred times over. But why do we call them galaxies at all rather than just star clusters? The reason, in short, is that they have dark matter — lots of it.

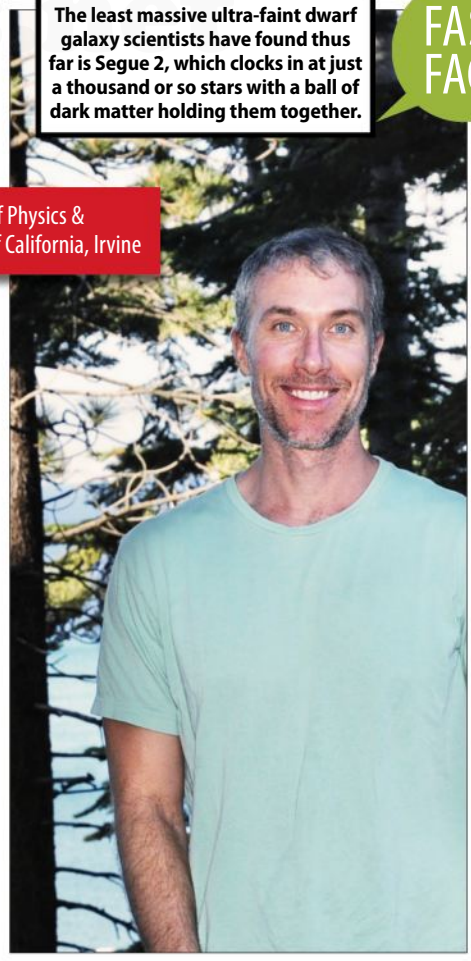
Most ultra-faint dwarf galaxies have a hundred times more dark matter than they have stars. Compare this to the disk of the Milky Way, where the ratio of normal to dark matter is about equal. Ultra-faint dwarfs are basically balls of dark matter with a few stars thrown in that help us find them.

The implication is that the universe is teeming with small dark matter clumps in the form of dwarf galaxies. The fact that there are so many of them is important because it sheds light on what dark matter is. We know, for example, that the dark matter particle cannot be too low in mass, or else these little dwarf galaxies would not exist. Similarly, the mass *density* of dark matter in the cores of these dwarf galaxies may provide clues to more subtle properties of the dark matter particle, such as how readily one scatters off another.

The next decade promises to be a golden age for the discovery and characterization of tiny dwarf galaxies, a renaissance fueled by larger sky surveys and more powerful telescopes. Though far less spectacular than their giant spiraled cousins, these puny galaxies may prove to be far more important in our hunt to understand dark matter.

FAST FACT

The least massive ultra-faint dwarf galaxy scientists have found thus far is Segue 2, which clocks in at just a thousand or so stars with a ball of dark matter holding them together.



COURTESY JAMES BULLOCK

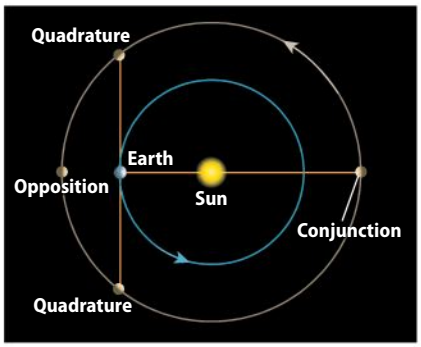
ASTRO**NEWS**

POLICY PERSONNEL. On July 29, NASA named Ellen Stofan, a planetary geologist, the agency's new chief scientist. Stofan will be Administrator Charles Bolden's principal advisor on science programs, strategic planning, and investments.

FAST FACT

Mars takes 780 days to move from one conjunction or opposition to the next. Jupiter takes 399 days.

PLANETARY LINEUPS



FEELING SUPERIOR. As superior planets (those farther from the Sun than Earth) orbit, they form a line with our star and Earth in two ways. If they lie on the opposite side of the Sun, astronomers call the event a conjunction; if on the same side of the Sun, it's an opposition. Because each superior planet moves some during a year, it takes Earth more than that span to catch up with them, which is why successive oppositions and conjunctions take longer than 365 days. At two points between conjunctions, the planet, Earth, and the Sun form a right angle. Astronomers call those points quadratures. *ASTRONOMY*: MICHAEL E. BAKICH AND KELLIE JAEGER

Astronomers find a natural particle accelerator

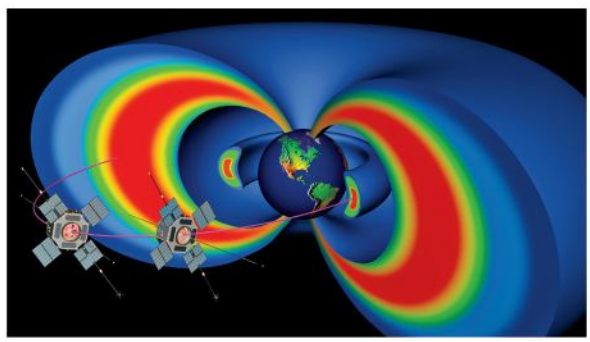
Two zones of charged particles called the Van Allen radiation belts surround Earth. According to a paper published July 25 in *Science* Express, radiation inside the belts boosts particles' energies and sends them flying at 99 percent of the speed of light.

Earth's protective magnetic field traps protons and electrons coming from space, predominantly from the Sun. These imprisoned particles form rings around Earth rather than penetrating the atmosphere and harming people and electronics. Once trapped, the particles travel almost as fast as light, but they don't arrive from space with such high energies, so scientists knew they must get their lift from somewhere. Until NASA's two Van Allen Probes took an in-depth look at the belts, no one knew what gave them their extreme speed.

The twin probes showed that the particles' energies begin to increase in the middle of the belts, and then the uptick spreads outward as particles receive kicks of energy from local electromagnetic waves. The bursts add up until the particles are almost as energetic — and thus as damaging to satellites — as they possibly can be.

Knowing where and how natural particle acceleration happens will help scientists protect satellites from the most dangerous of the Van Allen activity.

"This is one of the most highly anticipated and exciting results from the Van Allen Probes," says David Sibeck of NASA's Goddard Space Flight Center in Greenbelt, Maryland. "It goes to the heart of why we launched the mission." — **S. S.**



ATOM SMASHER. The twin Van Allen Probes study the radiation belts encircling Earth. In July, their observations showed that radiation inside the belts accelerate charged particles almost to the speed of light. JHU/APL/NASA

WorldMags.net

ASTRONEWS

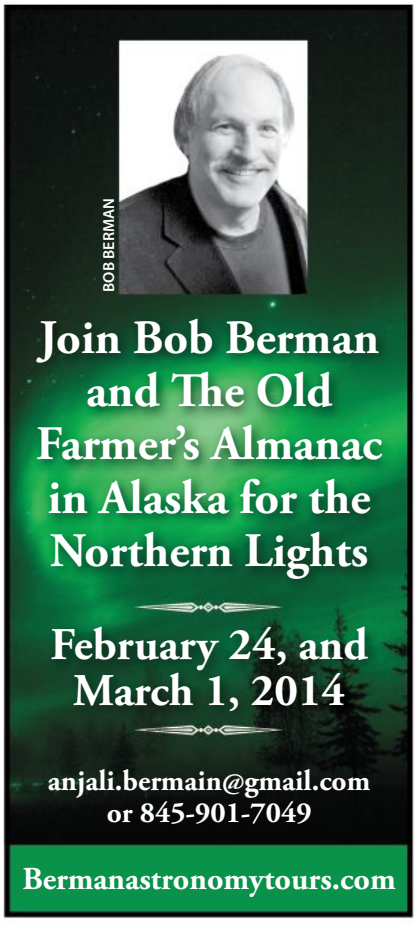


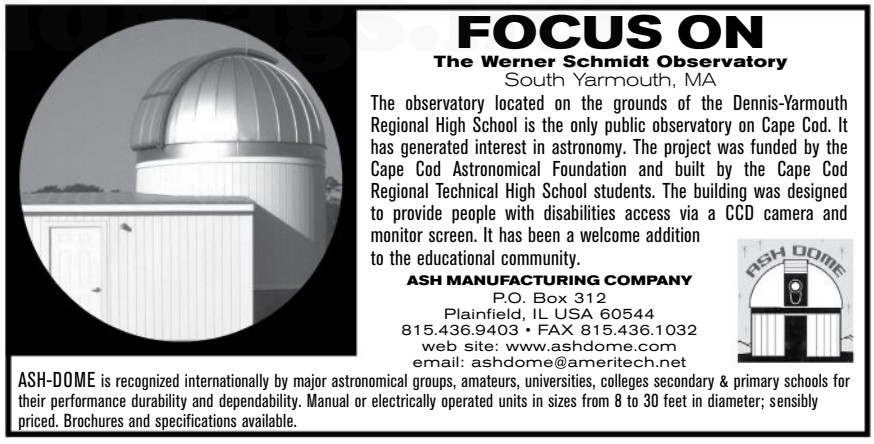
CERULEAN SPHERE. Researchers used the Hubble Space Telescope to discover that the exoplanet HD 189733b is blue. This is the first time they have deduced the color of another world. NASA/ESA/G. BACON (STScI)

Astronomers find that a planet is truly blue

Astronomers have been able to determine the masses, sizes, orbits, and atmospheric compositions of planets in other solar systems for years. But on July 11, NASA announced that for the first time, they know what the true color of a planet is: HD 189733b, located 63 light-years away, is "cobalt blue."

Although its hue may make the planet appear Earth-like, it is anything but. Its surface reaches 2000° Fahrenheit (1090° Celsius), and a 4,500 mph (7,200 km/h) wind tosses tiny drops of glass around. These glass "raindrops" scatter blue light more than red light, a phenomenon that gives the world its tint. — **S. S.**





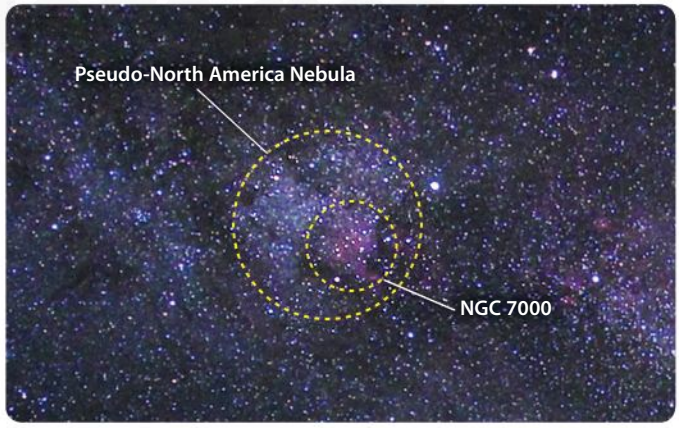




BY STEPHEN JAMES O'MEARA

A continent within

The North America Nebula is a celestial continent embedded inside another continent.



The real North America Nebula (NGC 7000) shows its coasts prominently and stands out from the surrounding stars, but only in a photographic view. ADAM BLOCK/NOAO/AURA/NSF

This November, go out after sunset and look in the western sky for Deneb, the Alpha (α) star of Cygnus the Swan. If you're under dark skies with the Milky Way blazing, look for the patch of light that contains the emission nebula NGC 7000, more commonly known as the North America Nebula.

This 2° by 1.5° island of misty radiance is an enormous region filled with Hydrogen-II plasma — charged hydrogen found in areas of recent star formation. It is some 2,000 light-years distant and contains the fainter Pelican Nebula (IC 5070). The complex lies 3° east of Deneb, just northwest of 4th-magnitude Xi (ξ) Cygni. Ultraviolet radiation from a massive O-type star strips electrons from the local hydrogen atoms. But after these electrons recombine with the atoms, they emit Hydrogen-alpha light, which appears red. You see mostly this light when you look at the North America Nebula.

NGC 7000's radiance resembles its continental namesake only by coincidence: Fortunately placed intervening dust clouds, which block emission, create its shape and outline it in darkness. The most prominent cloud appears to trace the eastern seaboard before curling into the Gulf of Mexico like the letter J.

Commonly thought of as a photographic object, the nebula resides in a star cloud that is a fine binocular target. Some keen-eyed observers even have detected the nebula itself without optical aid … or have they?

When I was younger, I, too, used to challenge myself to see the North America Nebula, and see it I did — or so I thought. When I moved to the dark skies of Hawaii, I realized my mistake.

Pseudo-continent

What I thought for years was the North America Nebula actually was the larger star cloud. In images, this complex appears divided into at least four segments because of its size. It mimics the shape and orientation of NGC 7000, but the real North America Nebula lies within, forming a wedge of starlight between the star cloud's pseudo-Bangor, -Houston, and -Miami.

In the pseudo-continent, Deneb sits near the position of Halifax, Nova Scotia. The entire western edge of NGC 7000 marks the Gulf Coast, from the southern tip of Texas to Tampa, Florida, and beyond. The dark gulf itself embays Xi Cygni, while the star 68 Cygni, 2° to the east, lies near the position of Mexico City. The West Coast of the United States runs 4° to the northwest, where the star 63 Cygni lies on the border of Washington state and British Columbia. The pseudo-North America measures a healthy 5° across, making it more than two times larger in extent than the real North America Nebula.

The real deal

What we see unaided at NGC 7000's location is mostly a vast star cloud atop the fainter nebula. When stars crowd together, they appear fuzzy, as the eye has difficulty resolving the multitude; that's why the naked-eye Milky Way looks, well, milky.

It's hard to tell how much of NGC 7000's nebulosity we see, if any. To find the real nebula, look for an obvious wedge of bright Milky Way in the aforementioned location. First identify Deneb and Xi Cygni, and then look between these stars for an isolated triangular patch of Milky Way. The dark nebulae in the region will help you separate it from the rest of the surrounding stars. Remember to use averted vision. Staring at it for a prolonged time (which you're usually told to avoid) enhances dark regions as your eyes become fatigued.

Viewing through small binoculars under dark skies helps bring out the true continental form quite strikingly. Still, it's difficult to tell whether you're seeing nebulosity or just congested starlight.

The use of a nebula filter will make the ghostly glow stand out, albeit faintly. The view changes dramatically through larger binoculars, however, when NGC 7000's brightest regions stand out independently of the surrounding patch of starlight, etched ever so cleanly by rivers of darkness. This view holds true if you switch to looking at the nebula through a telescope with a wide field of view. But consider going naked-eye first!

As always, let me know what you see (or what you don't see) at sjomeara31@gmail.com.

COSMIC WORLD

A look at the best and the worst that astronomy and space science have to offer. **by Sarah Scoles**

Cold as space — Supernova hot

Keeping score



After kids in New Delhi find a space rock, public educator Sachin Bahmba says, "Indian students have beaten students all over the world in asteroid discoveries." But who's counting?

Cashteroid



Planetary Resources (PR) nets $1.5 million on Kickstarter for the crowd-controlled Arkyd telescope. Awesome! Except that PR's investors are worth 50,000 times that. Don't tell.

Amped up



Venus' wind speeds shot up from 186 to 249 mph (300 to 400 km/h) during the Venus Express mission. The planet may have watched one too many episodes of *Breaking Bad*.

Science sorority



Grand Central Publishing releases *The Astronaut Wives Club*, the story of the women married to Mercury 7 astronauts, a.k.a. the real housewives of low Earth orbit.

ESA (KEEPING SCORE); NASA (CASHTEROID); ESA/MPS/DLR/IDA (AMPED UP); NASA (SCIENCE SORORITY)

ALL SKY CAM
Day and night
View from anywhere
360° horizon to horizon
660-675-5066
www.MoonglowTech.com

TELEVUE®
The Skylight
AR101/15
Optics by TeleVue
www.skylight-telescopes.com

CAMBRIDGE

"David J. Eicher has written a wonderful, up-to-date book on the history and science of comets. The book is written in a more conversational style, with occasional humor thrown in, and is not too technical. The result is a very enjoyable read for everyone."
– Gary W. Kronk, author of the *Cometography: A Catalog of Comets series*

A must-have guide!

COMETS!
Visitors from Deep Space
Written by David J. Eicher, editor-in-chief of ***Astronomy*** Magazine
Foreword by David H. Levy



Join David J. Eicher in exploring these mysterious cosmic bodies. This beautifully illustrated book describes the science behind comets, their role in human culture, and the secrets they may reveal about our universe. The author also offers an expert guide for successfully observing and imaging comets on your own.
250 pp: Pb: 978-1-107-62277-7: List Price: $24.99

New Edition!

Deep Sky Companions: The Messier Objects, *Second Edition*
Stephen James O'Meara
350 pp: Hb: 978-1-107-01837-2: List Price: $50.00

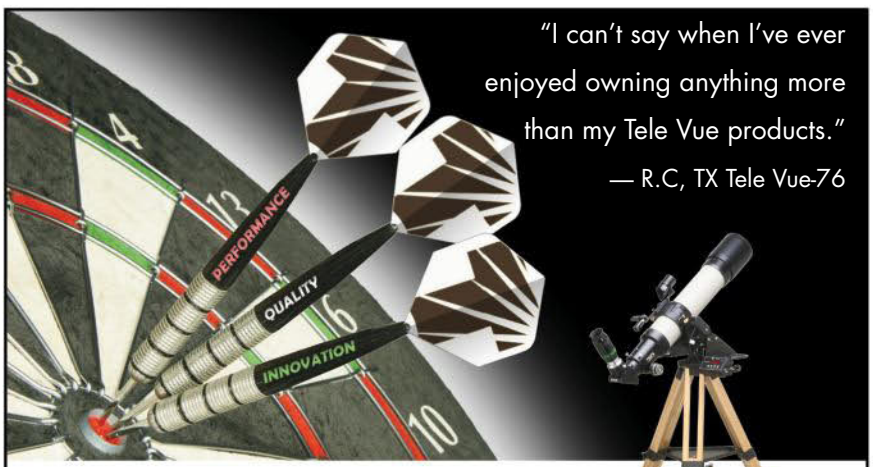


Prices subject to change.

Most titles now available in electronic format.
Visit **ebooks.cambridge.org** to browse all books.

View the Amateur Astronomy Online Catalog at
www.cambridge.org/us/astronomy
@CambUP_astro

CAMBRIDGE UNIVERSITY PRESS



"I can't say when I've ever enjoyed owning anything more than my Tele Vue products."
— R.C, TX Tele Vue-76



Why Are Tele Vue Products So Good? Because We Aim to Please!

For over 30-years we've created eyepieces and telescopes focusing on a singular target; deliver a customer experience "...even better than you imagined." Tele Vue products provide an observing experience as exquisite in performance as it is enjoyable and effortless.

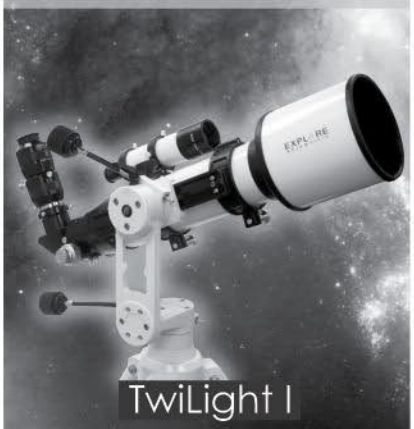
Pneumatic Air-Chair

NP101 f/5.4 APO refractor with 110° Ethos-SX eyepiece shown on Gibraltar Mount with Sky Tour digital setting circles.

And how do we score with our valued customers? Judging by superlatives like: "truly amazing, awesome, beautiful, work of art, exceeded expectations by a mile, best quality available, WOW, uncompromised, gorgeous" etc., BULLSEYE! See these warranty card superlatives in context at TeleVue.com/comments.

32 Elkay Drive, Chester, New York 10918 845.469.4551 www.TeleVue.com

Grab & Go!





Sometimes you want your telescope, and you want it now! However, if you have a nice, medium sized refractor and an uncomplicated alt-azimuth mount at the ready, then it is easy to get outside and begin observing in just a few minutes. That can be a real benefit on lots of occasions, whether the moon beckons, or a comet is hanging near the horizon, threatening to set into the west while you are still getting your 12" OTA out of its case! ***Enter the Explore Scientific TwiLight Mounts!***

EXPLORE SCIENTIFIC
explorescientific.com - 866.252.3811
©2013 Explore Scientific, LLC

SBIG
ASTRONOMICAL INSTRUMENTS
NO COMPROMISES
THE NEW STT CAMERAS:
COOLING DELTA GREATER THAN -55C
LESS THAN 1 SECOND DOWNLOAD
SELF-GUIDING IN FRONT OF FILTERS
MICRON-PRECISION FILTER WHEEL
INTERNAL IMAGE PROCESSING
ETHERNET AND USB 2.0 INTERFACE
AND MORE ...
www.sbig.com
Santa Barbara Instrument Group
150 Castilian Drive, #101
Santa Barbara, CA 93117 USA
(805) 571-7244 sbig@sbig.com

ROLLING STONE. Martian meteorite NW 5298 arrived 20 million years ago, 4 billion years later than scientists thought, according to the July 25 *Nature*.

SPACE SCIENCE UPDATE

MYSTERIOUS RADIO BURSTS SPOTTED



SWINBURNE ASTRONOMY PRODUCTIONS

BRIGHT BLAST. Astronomers using the Parkes 64-meter radio telescope detected four extremely luminous radio bursts — one such blast is at the upper left of this photo illustration. They aren't sure what causes these signals, which might originate some 11 billion light-years away.

Six years ago, astronomers detected a brilliant burst of radio waves that lasted a few milliseconds, but they couldn't associate the blast with a specific object. In the July 5 issue of *Science*, Dan Thornton of the University of Manchester and colleagues reported seeing four other mysterious radio bursts. These had similar energies to the 2007 discovery and also appeared just once. While the researchers still don't know what causes such an intense signal, they can now say for sure that the first detection wasn't a fluke.

In the most recent study, scientists were scanning the sky with the 64-meter Parkes radio telescope in New South Wales, Australia. They were looking specifically for the rapidly spinning compact remnants of once massive stars, called neutron stars, and other transient radio sources. The four newly observed bursts occurred in the high latitude of the Southern Hemisphere, some 40° south of the Milky Way's disk.

To determine how far away these four bursts originated, the astronomers analyzed the signals. As radio radiation travels through gas and dust, it bounces off electrons, which smears the signal. These four bursts' emissions showed such a smearing, indicating the bursts were from space and not from Earth. But because they didn't occur in the galaxy's disk (which is where material in the Milky Way is densest), the astronomers think these blasts originated from outside the Milky Way. They calculated how much material the radiation had to travel through — space outside the galaxy also contains gas and dust — to get to the Parkes telescope on Earth, and that corresponds to the bursts' distances: between about 5.5 and 10.5 billion light-years.

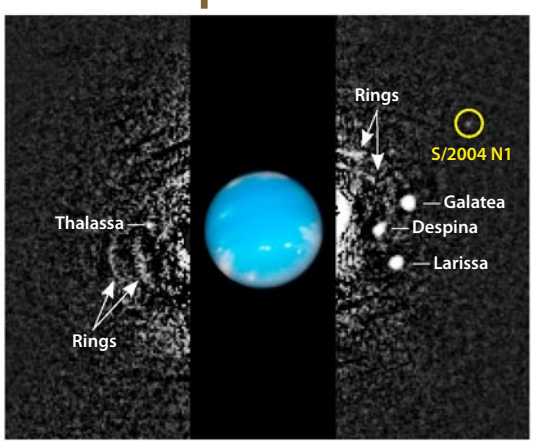
In just a few milliseconds, each of these four blasts released more energy than the amount the Sun puts out in 3,000 years. Narrowing down what's causing these blasts, however, has been difficult. Thornton's team didn't find any gamma-ray, X-ray, or optical radiation at the same positions as the radio bursts. The astronomers say in their *Science* paper that the most convincing cause of the radio bursts involves extremely magnetic neutron stars called magnetars. However, future all-sky radio surveys — set to come online in the next decade — should help astronomers find many more such radio blasts, which will allow them to figure out what causes them. Thornton and colleagues suggest that 1,000 of these bursts occur across the sky every day. **— L. K.**

Scientist discovers new Neptune moon

SMALL SATELLITE. The most distant planet's family has grown by one member, as NASA announced July 15 the discovery of a 14th moon orbiting Neptune.

The small satellite, which scientists designate S/2004 N1, showed up on archival photos from the Hubble Space Telescope. While studying Neptune's ring segments, SETI Institute's Mark Showalter noticed a white dot about 65,400 miles (105,250 kilometers) from the planet that appeared in more than 150 images taken between 2004 and 2009. By plotting its changing position, he found that it completes a revolution every 23 hours.

Scientists estimate that the new moon is no more than 12 miles (19km) across, making it the smallest of Neptune's known satellites. **— K. F.**



NASA/ESA/M. SHOWALTER (SETI INSTITUTE)

WorldMags.net

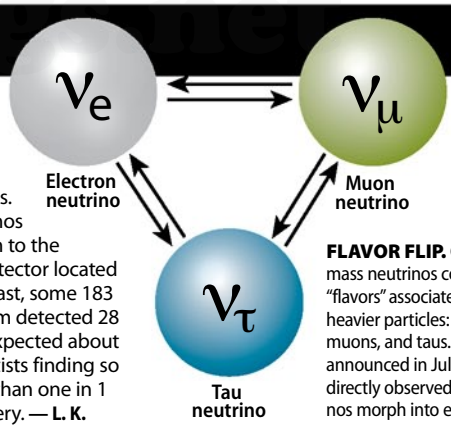
FAST FACT

Scientists first discovered neutrinos in 1956. Six years later, they found that nature creates multiple types, or "flavors," of these particles.

Particle conversion confirmed

Ghostly low-mass neutrinos interact weakly with other matter (they can pass through Earth without colliding with other mass). These particles come in three types: one associated with the electron and two associated with the electron's more massive cousins, the muon and tau. Some 15 years ago, scientists found that neutrinos could morph from one type to another, a process called oscillation. And on July 19 at the European Physical Society meeting in Stockholm, physicists with the Tokai to Kamioka Experiment announced the direct observation and confirmation that muon neutrinos had oscillated into electron neutrinos.

They sent beams of muon neutrinos from Tokai on the east coast of Japan to the Super-Kamiokande underground detector located at Kamioka on the country's west coast, some 183 miles (295 kilometers) away. The team detected 28 electron neutrinos, whereas it had expected about 4.6. The random chance of the scientists finding so many more of these particles is less than one in 1 trillion, which confirms it as a discovery. **— L. K.**



ASTRONOMY: ROEN KELLY

FLAVOR FLIP. Ghostly low-mass neutrinos come in three "flavors" associated with three heavier particles: electrons, muons, and taus. Scientists announced in July that they directly observed muon neutrinos morph into electron ones.







WorldMags.net

MOBILE UPDATES »
Scan the code to access the latest news and observing info from your mobile device.

Year of the Comet

Your home for Comet ISON information

A dazzling comet can ignite a viewer's passion better than almost any other celestial object. And those flames will burn bright this year as 2013 promises what could be the most magnificent comet of the 21st century thus far. As Comet ISON (C/2012 S1) makes its closest approach to the Sun on November 28, it could shine at a brilliant magnitude –4.5 — equaling the brightness of Venus.



To make sure readers have all the best observing information and can experience the beauty of the comet for themselves and through astroimagers' most stunning photographs and videos, *Astronomy*'s editors are devoting a whole section of Astronomy.com to the "Year of the Comet." Head to **www.Astronomy.com/ISON** for finder charts, images, observatory news, prediction updates, observing tips, videos, and more of Comet ISON as it makes its first visit to the inner solar system. And we want your involvement to help us make the most of this potentially historic event. If you have images, observing reports, planned star parties, or suggested updates to share about Comet ISON, send them to Senior Editor Michael E. Bakich at mbakich@astronomy.com. This fall should be a great time for amateur astronomy.



COMET IMAGES: NASA/ESA/ THE HUBBLE HERITAGE TEAM (STScI/AURA)

FOLLOW *ASTRONOMY* www.twitter.com/AstronomyMag www.facebook.com/AstronomyMagazine

OBSERVING TOOLS

StarDome

Astronomy's interactive star chart is a great tool for planning your night of observing or for simply checking when a specific planet or deep-sky object will appear in your sky. Customize the map for the time of day, and StarDome will show you what constellations, planets, comets, and more are visible from your location. The program holds a database exceeding 2,500 objects, including each target's celestial coordinates and current magnitude. Get acquainted with the night sky or plan your next observing session at **www.Astronomy.com/stardome**.

COMMUNITY



Reader Photo Gallery

Browse thousands of beautiful astroimages like this one of Omega Centauri by Samuele Gasparini. Submit your own images at **www.Astronomy.com/readergallery**.

Community Events

Find star parties or lectures in your area or post an invite to your astronomy club event at **www.Astronomy.com/events**. It's a great way to get to know others who share your passion about our night sky or to introduce your local community to the hobby.

REGISTER TODAY! Go to www.Astronomy.com/register for access to bonus articles, photos, videos, and more.

Comet Discussion Panel
The Arizona Science and Astronomy Expo celebrates a year of great comets by hosting a panel discussion about comets on Sunday afternoon, November 17, 2013.

ARIZONA SCIENCE & ASTRONOMY EXPO
NOVEMBER 16-17, 2013
TUCSON CONVENTION CENTER
TUCSON, AZ

Two day Southwest Astrophotography Seminar hosted by Warren Keller with classes conducted by some of the best astro imagers & astrophotographers in the world!

Second Annual Event
in Southern Arizona with many exciting exhibits, speakers, vendors and more!
- World-renowned speakers:
 Story Musgrave - retired NASA Astronaut.
 Timothy Ferris - Scientific Author, Professor, Film Maker.
 Dr. Alexei Filippenko - Astrophysicist & Professor at the University of California Berkley.
- Exhibitors and manufacturers of astronomy products from around the world.
- Digital planetarium shows.
- Daily solar observing with Stephen Ramsden of CBSAP, Randy Shivak & Lunt Solar systems.

Expo Admission & Hours:
Sat., Nov. 16, 8:30 AM to 6 PM: $10 –
access to all exhibits and speakers
Sun., Nov. 17, 10 AM to 5 PM: $10 –
access to all exhibits and speakers; free admission for Veterans
Children 12 and under are free both days when accompanied by adult.
Be sure to check our website for the latest information:
www.scienceandastronomy.com
Connect with us on Facebook:
www.facebook.com/groups/ASAExpo/

EXPO HOSTED BY:
CELESTRON, PlaneWave Instruments, Lunt Solar Systems, astronomics ... our 31st year, STELLARVUE, TelescopeS.NET

Photo by Wally Pacholka

DC-3 Dreams, SP, EXPLORE SCIENTIFIC, Orion Telescopes & Binoculars, AVALON INSTRUMENTS, Vixen Optics, Sky-Watcher, STARIZONA ADVENTURES IN ASTRONOMY & NATURE, DEEP SPACE PRODUCTS, AIS Apogee IMAGING SYSTEMS, Optec, iOptron, Starlight Xpress, 10 MICRON, OPT

ARIZONA SCIENCE & ASTRONOMY EXPO

NOVEMBER 16-17, 2013
TUCSON ARIZONA

EXHIBITS, SPEAKERS, VENDORS, SOLAR OBSERVING

Celestron
310-328-9560
www.celestron.com

Get on Comet Watch with Celestron! Come check out our special Cometron products, as well as our other innovative telescopes, binoculars, and digital microscopes.

Chroma Technology
800-824-7662
www.chroma.com

Employee-owned and based in Vermont, Chroma offers durable non-reflective optics for precise color separation and signal purity.

Deep Space Products
info@deepspaceproducts.com
www.deepspaceproducts.com

See us for HyperTune® services and TEMP-est systems; 10Micron, Avalon and AGOptical products; ADM, Berlebach, Starlight Instruments and TPI Astro accessories.

Lunt Solar Systems
877-344-7343
www.luntsolarsystems.com

20 years of optical design, testing, and manufacturing of ultra precision flats, mirrors, filters, and etalon assembles. 12 years direct experience with solar related systems.

PlaneWave Instruments
310-639-1662
www.planewave.com

PlaneWave Instruments is committed to providing observatory-class products for serious astronomers at an unprecedented value.

Polytank/Explora-Dome
800-328-7659
www.explora-dome.com

Stop by. See, feel the quality of our domes.

SBIG (Santa Barbara Instrument Group)
925-463-3410
sbig@sbig.com
www.sbig.com

Visit our booth for the innovative, cutting edge products that the astronomy community has come to expect.

Sky-Watcher USA
Toll-free: 885-327-1587
http://www.skywatcherusa.com

Sky-Watcher USA is bringing a whole new experience to owning a telescope. If you're ready for high-quality products and attentive service, then you're ready for Sky-Watcher USA.

Software Bisque
303-278-4478
sales@bisque.com
www.bisque.com

Please visit the Software Bisque booth to check out the Paramount ME II Robotic Telescope Mounts, TheSky, and more.

Stellarvue
530-823-7796
www.stellarvue.com

Stellarvue® designs and handcrafts the finest refractor telescopes and provides programs and experiences to foster and to encourage individual exploration of the universe.

Tele Vue Optics, Inc.
845-469-4551
www.televue.com

Come to the Tele Vue booth (#423) and test drive all of our eyepieces and APO refractors. You know you want to!!

Vixen Optics
949-429-6363
www.vixenoptics.com

When Quality Matters, Vixen is the clear choice. New Sphinx Mounts with STAR BOOK TEN,® the amazing Polarie Star Tracker & new scopes!

WorldMags.net

THE SCIENCE

Scientists have sent 12 missions to explore comets. Here's what they've

Comets capture our attention today just as they did in ages past — even if the reasons are perhaps different. A bright comet makes people gaze into the heavens in wonder, and that ability has not dwindled in the current era of television, smartphones, and the Internet. If anything, these technological advances make it easier for people to learn about comets and see them.

These objects have drawn both the scrutiny and fascination of mankind for thousands of years, and our understanding of comets has evolved over that time. What we've discovered about cometary compositions and origin locations is surprisingly recent, and this knowledge has advanced tremendously with the launch of spacecraft to study them up close.

Ancient history

While the first proto-humans who started paying attention to the heavens undoubtedly noticed comets, one of the oldest surviving records dates to around 300 B.C. A silk unearthed from a Han Dynasty tomb at Mawangdui in Changsha, China, displays stylized drawings of 29 comets, implying that Chinese astronomers had been carefully noting comet appearances for hundreds of years before documenting them on this fabric (see p. 26). Over the ensuing centuries, nearly every culture around the world recorded comets. While most surviving records lack the details of modern observations, they continue to be useful to us in linking comets of today with those of the past.

Historically, observers did not know the nature of comets, and thus their unexpected appearances often were considered harbingers of doom. The unusual motions of comets across the sky deviated from the predictable patterns of the stars and planets, so many believed these objects were atmospheric phenomena. As the scientific method developed, careful observations eventually revealed that comets orbit the Sun. Further study yielded an improved understanding of their compositions and behaviors, but the first comprehensive and correct model of comets did not arrive until the middle of the 20th century. Not until the past few decades, when spacecraft actually visited comets, have we been able to confirm their true natures.

Dirty snowballs

In 1950, Fred Whipple of Harvard University in Cambridge, Massachusetts, proposed that comets are icy conglomerates, or "dirty snowballs." The basic idea is that a chunk of ice and dust — the "nucleus" — approaches the Sun, and the rising temperatures cause ice near the surface to turn directly into gas, or sublimate. The escaping gases drag small grains of dust off the nucleus to create a diffuse cloud of material, called the coma, surrounding the nucleus. The Sun's wind of particles and radiation sweeps away

Matthew Knight *researches comets primarily using Lowell Observatory's 42-inch Hall Telescope and its new 4.3-meter Discovery Channel Telescope, both located at dark-sky sites near Flagstaff, Arizona.*

WorldMags.net



Since 1985, nine spacecraft have visited seven comets, providing scientists a tremendous amount of information about these objects.
ASTRONOMY: ROEN KELLY

OF COMETS

learned about these relics from the early solar system. **by Matthew Knight**

WorldMags.net



When archaeologists unearthed a group of Han Dynasty tombs at Mawangdui in Changsha, China, in the 1970s, they found this atlas of different comet shapes and what disasters the ancient culture associated with each. HUNAN PROVINCIAL MUSEUM

the gas and dust from the coma to produce two familiar "tails" — one of gas and another of dust.

Whipple's insight ushered in a new era of comet studies. Soon thereafter, astronomers began widespread and systematic investigations of these objects for the first time. Over the ensuing decades, advances in telescope technology and research techniques allowed us to study comets in wavelengths of light not used before. Spacecraft missions to comets beginning some three decades ago augmented this research and provided observations of a select handful of these dirty snowballs.

We now know that comet nuclei are relatively small (typically a few kilometers across), darker than coal, and about half as dense as water. They have irregular shapes, with differing topography across their surfaces that also changes with time. Much of the material we see in the coma comes from active areas that cover only a small fraction of the surface, and the gases often leave these regions in jets. The sublimation of water ice drives most of the activity that we observe, but other frozen gases — like methane, ammonia, carbon monoxide, and carbon dioxide — contribute as well. From modern studies of these gases, we have gained valuable insights into the compositional diversity of comets and traced their makeup to the solar system's regions in which they formed. So, even though comets remain mysterious because of their unpredictability, we understand reasonably well their general physical properties — which really aren't too different from Whipple's original idea.

Giotto to Rosetta and beyond

The first spacecraft to visit a comet was the International Sun-Earth Explorer 3/International Cometary Explorer. The probe didn't carry a camera, however, so many forget its 1985 encounter with Comet 21P/Giacobini-Zinner. Soon thereafter, an armada of five spacecraft — the European Space Agency's (ESA) Giotto, the Soviet Vega 1 and 2, and Japan's Suisei and Sakigake — intercepted Comet 1P/Halley in 1986. Giotto's now iconic image of Halley's nucleus (see p. 28) unequivocally showed that the gas and dust originated from just a few discrete areas on the surface of the roughly 6-mile-wide (10 kilometers) nucleus, thus confirming the dirty snowball model. Giotto went on to visit Comet 26P/Grigg-Skjellerup in 1992, although its camera was no longer working.

While it would be nearly a decade before spacecraft again visited a comet, the next flyby began a golden age of exploration, with these encounters becoming almost routine. In 2001, NASA's Deep Space 1 flew past Comet 19P/Borrelly following an earlier rendezvous with Asteroid 9969 Braille. In 2004, NASA's Stardust flew through the coma of Comet 81P/Wild and collected samples of dust grains, returning them to Earth in 2006 via capsule. In 2005, the space agency's Deep Impact released a probe that intentionally crashed into the nucleus of Comet 9P/Tempel to expose its interior. NASA then recommissioned the surviving Deep Impact flyby spacecraft as EPOXI (Extrasolar Planet Observations and Characterization [EPOCh] combined with the Deep Impact Extended Investigation [DIXI]), which flew past Comet 103P/Hartley in 2010. Meanwhile, the Stardust spacecraft became Stardust-NExT (Stardust-New Exploration of Tempel) and visited Comet Tempel in 2011; team members timed the craft's encounter to re-image the Deep Impact crater.

In early 2014, ESA's Rosetta mission will rendezvous with Comet 67P/Churyumov-Gerasimenko. It will orbit the comet for more than a year and send a small lander to the body's surface. This is the first long-term mission on a comet, and we hope it will reveal how these interlopers behave as they approach the Sun and their activity increases. The lander will remain on the nucleus for at least a week and return the first close-up studies of a comet's surface.

Right now, no space agency has definitive plans for any missions to comets after Rosetta ends in 2015, but the logical next step would be to land on a nucleus, extract samples from the surface and interior, and return the still-frozen samples to Earth. This would undoubtedly produce groundbreaking science in our quest to reveal how the solar system formed and evolved — one of the primary reasons we study comets.

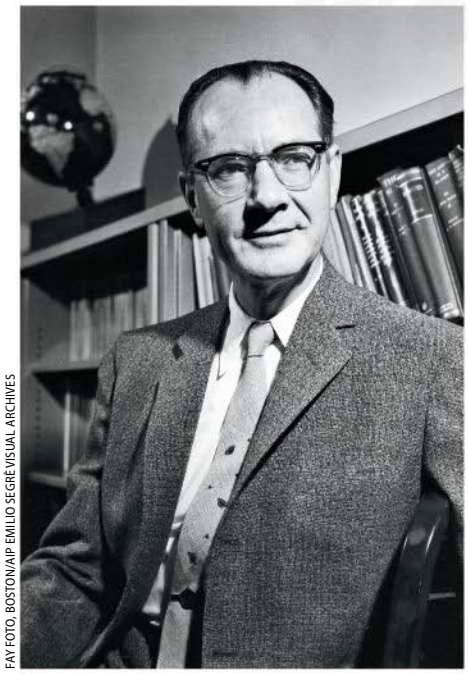
The logical next step would be to land on a nucleus, extract samples from the surface and interior, and return the still-frozen samples to Earth.

Where do comets come from?

Our increased understanding of comets has come not just from discoveries based on ever-improving ground- and space-based observations, but also from increased computing power that has enabled the simulation of orbits of many millions of comets over the lifetime of the solar system. A general picture of the evolution of our planetary system has emerged that explains many of the details of the distribution of comets we see today, and we find that the planets and small bodies (like asteroids and comets) have undergone a surprising amount of migration.

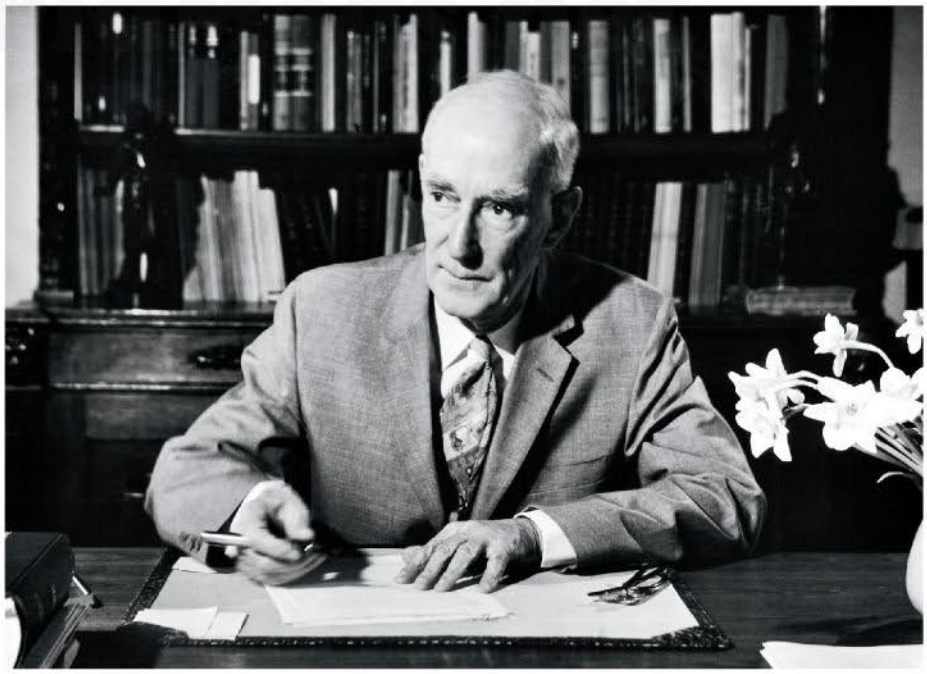
Because comets are composed of substantial quantities of water ice, they likely formed beyond the "frost line" where ices can arise and roughly

WorldMags.net



FAY FOTO, BOSTON/AIP EMILIO SEGRÈ VISUAL ARCHIVES

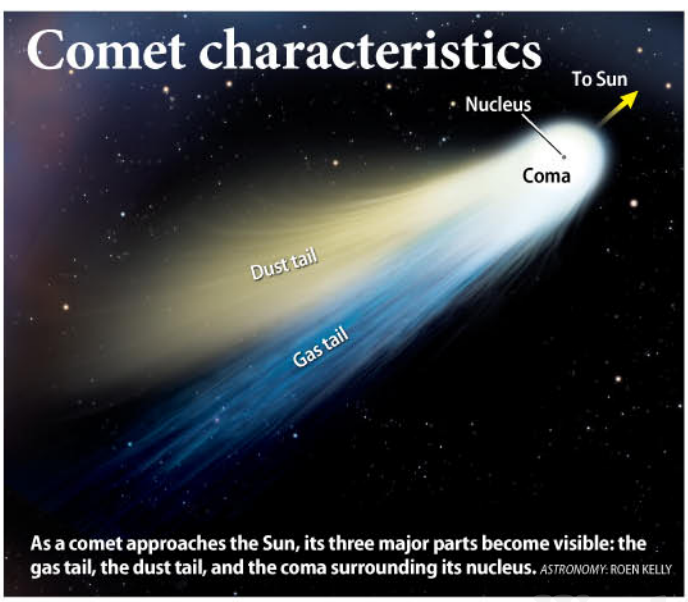
Fred Whipple proposed that comets are conglomerates of ice and dust. Modern observations continue to support his theory — 63 years later.



In 1950, Jan Oort suggested that comets originate from a cloud extending to perhaps 150,000 times the Earth-Sun distance. This Oort Cloud, as astronomers now call it, is still thought to be a major comet reservoir, even though it hasn't been directly observed yet. © THE LEIDEN OBSERVATORY

between the present distances of Jupiter and Pluto, so at least 5 astronomical units from the Sun (1 AU is the average Earth-Sun distance). Comets also must have resided beyond this distance until recently for the ices to survive.

The giant planets appear to have migrated early in the solar system's lifetime, scattering the smaller objects, including the proto-comets. Gravitational interactions flung some into the inner solar system, and a substantial number impacted Mercury, Venus, Earth, Mars, and the Moon. We can still see the record of this "Late Heavy Bombardment" in the increased number of impact craters on the Moon that date to between 3.8 and 4.1 billion years ago. Other small objects remained in the plane of the solar system but were pushed outward beyond Neptune. These objects have remained in stable orbits between 30 AU and 50 AU in what is now known as the Kuiper Belt, the most famous member of which is Pluto.



As a comet approaches the Sun, its three major parts become visible: the gas tail, the dust tail, and the coma surrounding its nucleus. *ASTRONOMY:* ROEN KELLY

The remaining proto-comets moved outward to greater distances from the Sun. Many had enough velocity to escape our star's gravity and now drift between stars as "interstellar comets." Those moving just a bit too slow to escape ended up in randomly inclined orbits at the farthest reaches of the solar system. They make up a shell of icy bodies some 2,000 AU to 100,000 AU from the Sun known as the Oort Cloud. While we haven't observed an Oort Cloud object at these huge distances, the statistics of comet orbits clearly indicate a population of trillions of frozen objects. The proto-comets perturbed with even less energy were scattered into orbits stretching 10s to 100s of AU with a large range of inclinations. We have discovered a handful of these "scattered disk objects" (SDOs), also called "hot Kuiper Belt objects," notably the dwarf planet Eris.

Collectively, we call the icy objects orbiting beyond the eighth planet "trans-Neptunian objects" (TNOs). A gravitational perturbation — such as a passing star or galactic tides — may occasionally dislodge a TNO from its long, frigid orbit and move it closer to the Sun. If it reaches small enough distances, the Sun's radiation will cause its ices to sublimate and the object may become observable from Earth and thus be discovered as a comet.

We now recognize distinct classes of comets whose members have similar orbital characteristics and compositions. These groups trace back to different regions of origin and therefore give us clues to the conditions in the solar nebula out of which the planets formed.

Best known of these classes is the Jupiter family comets (JFCs); Hartley is a member. These objects typically have low-inclination orbits with periods of less than 20 years. JFCs are recent interlopers into the inner solar system from the scattered disk, and Jupiter's gravity trapped them into small orbits that extend to near that planet. JFCs show more surface evolution from solar radiation than other comet classes, which reflects the increased time they have spent in the inner solar system.

Centaurs, icy bodies in orbits between Jupiter and Neptune, are related to JFCs. These originated in the scattered disk, but their orbits have not evolved enough to reach the inner solar system, so

WorldMags.net



The European Space Agency's Giotto probe was the first to photograph a comet nucleus up close. In 1986, it imaged Comet 1P/Halley at a closest approach of just 370 miles (596 kilometers). Four other spacecraft visited the comet that same year. ESA/MPAE LINDAU

they are intermediaries between SDOs and JFCs. Centaurs are icy, but they never get close enough to the Sun for the ices to sublimate, so these objects generally appear inactive.

The remaining classes of comets resided in the Oort Cloud until some other object perturbed them, flinging them into the inner solar system. Long-period comets (LPCs) — like the one currently making headlines, Comet ISON (C/2012 S1) — have orbits with random inclinations and periods spanning thousands to millions of years. Many LPCs that reach the planetary region for the first time are so weakly bound to the Sun to begin with that they are ejected from the solar system by their gravitational interactions with the giant planets. Occasionally, interactions with the planets perturb an LPC into a smaller orbit spanning thousands of years; this is the case with Comet Hale-Bopp (C/1995 O1). This type of comet will travel well beyond the Kuiper Belt at its farthest distance from the Sun but will not return to the Oort Cloud. With the right series of perturbations, some LPCs' orbital periods shorten dramatically, to decades or centuries, and become "Halley-type comets" named for (you guessed it!) the first comet shown to have an orbit that brings it by the Sun on a set period, Comet Halley.

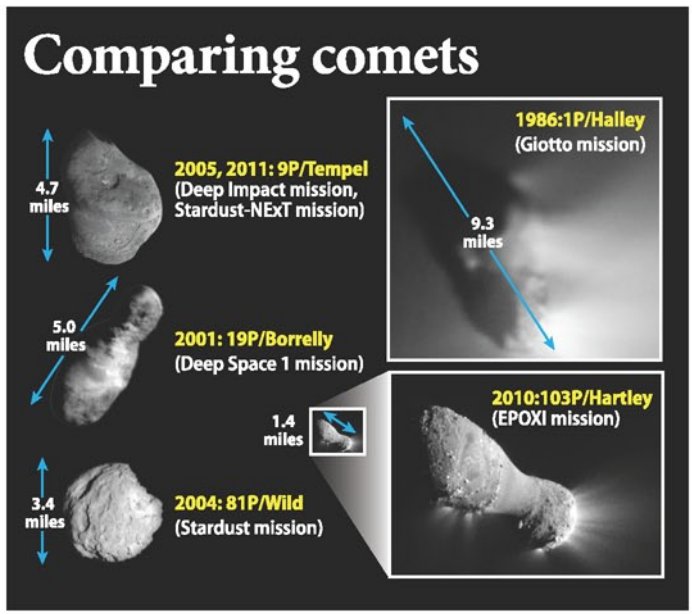
> Even as comets can be a threat to life today, they may have helped life take hold on ancient Earth.

When is a comet not a comet?

To distinguish comets and asteroids, we typically define the former as active, diffuse, and/or having a tail, while the latter appear pointlike and inert. Modern observations, however, have revealed a number of objects that blur the line between comet and asteroid. One example is a class called main-belt comets (MBCs), which are objects on classically asteroidal orbits that exhibit cometary characteristics. We think impacting bodies on these objects create the comet-like behavior in some cases by exposing small regions of subsurface ice, which leads to activity analogous to that seen in traditional comets; in a few cases, the impacts might generate short-lived clouds of dust that look like comas. In both cases, MBCs appear to have formed with the rest of the asteroids and not from the comet reservoirs described earlier.

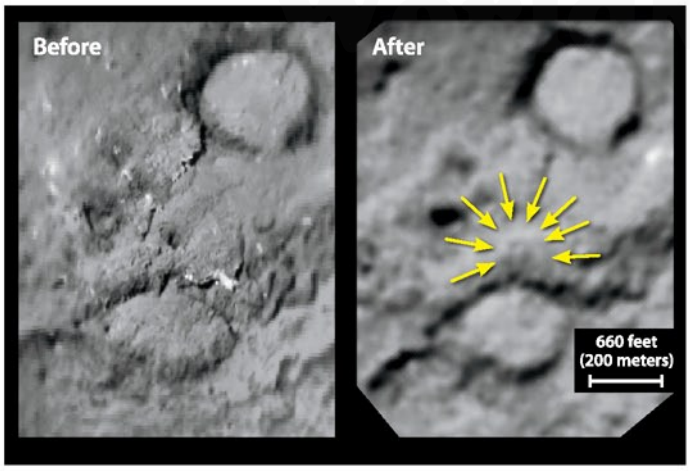
We also know of apparent asteroidal objects on comet-like orbits. Many are likely dead or dormant comets that have become inactive due to the complete loss of volatile ices at or near the surface, or from dust that built up to prevent sunlight from reaching the ices below. Because their small sizes and dark surfaces make them hard to detect when far away, dormant comets are found most frequently among the population of asteroids that come close to our planet's orbit, known as near-Earth objects. However, they likely exist throughout the solar system.

Another surprising discovery of the past couple decades is the existence of many thousands of small "sungrazing" objects. These are on highly eccentric orbits that pass extremely close to the Sun — just a few solar radii — and are generally too faint to see without a space-based solar telescope. Research has shown that most of these objects are fragments of larger known comets. However, we have been unable to link some to any known comets, which raises the possibility that they are actually asteroids that have been perturbed into sungrazing orbits. Due to the extreme radiation environment close to the Sun, rocks and metals that are ordinarily



Scientists have sent 12 missions to investigate comet nuclei. Here's how some of those dirty snowballs compare. NASA/JPL/UMD (9P/TEMPEL); NASA/JPL (19P/BORRELLY); NASA/JPL-CALTECH (81P/WILD); ESA/MPAE (1P/HALLEY); NASA/JPL-CALTECH/UMD (103P/HARTLEY)

WorldMags.net



The surface of Comet 9P/Tempel exhibits a scar from the Deep Impact probe's 2005 collision. The image at left shows the comet's surface as the probe neared its final destination, while the image at right was captured more than six years later as the Stardust-NExT (New Exploration of Tempel) craft flew by the comet. NASA/JPL-CALTECH/UNIVERSITY OF MARYLAND/CORNELL

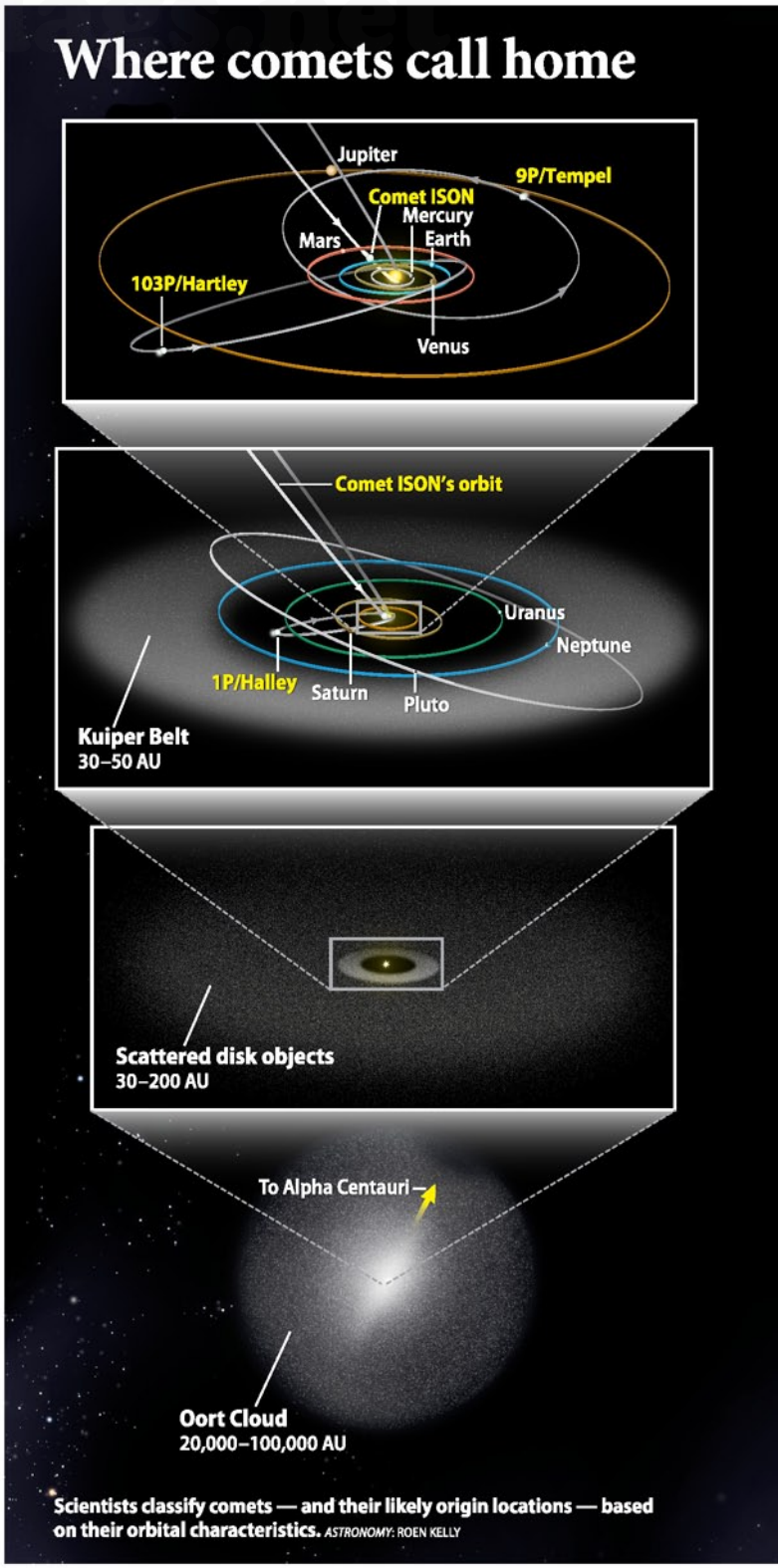
extremely stable in space will sublimate, and thus even an asteroid completely devoid of ices might appear cometary.

Facilitators of life and death

Comets' eccentric orbits often cross Earth's path, and while the chance of any given comet colliding with our planet is remote, given enough time and enough comets, collisions inevitably occur. No such collisions have happened in recorded history, but the February 2013 fireball over Chelyabinsk, Russia, serves as a reminder of the destruction that such an impact could cause. Preliminary research suggests that the meteoroid was initially 60 feet (18 meters) wide — about the size of a house. An impact by a typical cometary nucleus would cause orders of magnitude more damage. In fact, the impact of a comet or asteroid about 6 miles (10km) across — a rather average size for a comet — appears to have caused the extinction of the dinosaurs around 65 million years ago.

Impacts are an unavoidable part of living in the solar system, but fortunately there's little chance of a devastating one. Small dust grains collide with our planet all the time; we observe these as "shooting stars" in the night sky as they burn up in Earth's atmosphere. Impacts by objects the size of the Chelyabinsk meteoroid occur much less often, probably every few decades. Collisions with objects large enough to cause significant damage across a state-sized region are even more infrequent, likely millions of years.

Yet even as comets can be a threat to life today, they may have helped life take hold on ancient Earth. This is another of the primary reasons we study them. Comets carry many of the basic ingredients we think are necessary for life in the form of ices and dust grains containing large amounts of carbon, hydrogen, oxygen, and nitrogen — called "CHON" particles. During the Late Heavy Bombardment, the rain of small rocky objects, including comets, onto an early Earth delivered large quantities of these materials and likely brought enough water to fill our oceans. Comets may have helped transform a dry, barren planet into the blue marble we now occupy. Consequently, continued investigations of comets are highly relevant to the burgeoning study of planets around stars other than the Sun as we seek the holy grail of astronomy: life beyond Earth.



Scientists classify comets — and their likely origin locations — based on their orbital characteristics. *ASTRONOMY:* ROEN KELLY

We continue to research comets to answer the mystery of how life got to Earth and to learn valuable clues about how the solar system formed and evolved. While we now understand far more about comets than ever before, that knowledge does not diminish their grandeur. And if comets happen to put on a show while teaching us more about our place in the cosmos, then that's just icing on the cake.

VISIT **www.Astronomy.com/toc** TO WATCH A VIDEO OF WHAT THE EPOXI SPACECRAFT SAW AS IT FLEW BY COMET 103P/HARTLEY.

WorldMags.net

WorldMags.net

FROM SUPERSTITION



This 17th-century woodcut implies that the illustrated comet caused the weather, fire, and destruction on the left. Around the same time, those in England were worried that a comet was causing the bubonic plague. NASA/JPL

For thousands of years, scientists thought comets lived within Earth's atmosphere, and nearly everyone believed these celestial visitors delivered death and destruction with their tails. **by Gary Kronk**

A comet's sudden appearance out of twilight is one of the most exciting celestial events. But "excitement" can be either positive or negative. Until the past 100 years, the sight of comets' beautiful tails stretching across the celestial sphere was overshadowed by the belief that they were able to change the course of history on Earth.

Because comets are dramatic and different from any other bright lights in the sky, their origins, orbits, and compositions were difficult for early astronomers — and, in fact, scientists into the 20th century — to interpret. And from that lack of understanding came false associations and an undue sense of danger.

Gary Kronk *is the author of the five-part series* Cometography *(Cambridge University Press) and the catalog website www.cometography.com.*

WorldMags.net

WorldMags.net

TO SCIENCE



By the time Comet Lovejoy (C/2011 W3) appeared late in 2011, people did not consider comets to be harbingers of disaster. It swung just 0.0056 AU from the Sun, peaked at magnitude –2.9, and, unsurprisingly, caused no damage to Earth. WAYNE ENGLAND

Early comet chronicles

Observations of comets extend far into recorded history. The oldest accounts are inscribed on the "oracle bones" of ancient China. This collection contains 160,000 bones and turtle shells dating back to the Shang Dynasty, which existed from the 16th to 11th centuries B.C. Some mention *hui*, the Chinese term indicating a comet with a tail. One particular bone references appeasing a queen: "By making a sacrifice to Pi-keng, will the comet disappear?" Another bone calls attention to the changing shape of a "strange comet" and asks the question: "Will it bring darkness upon us?"

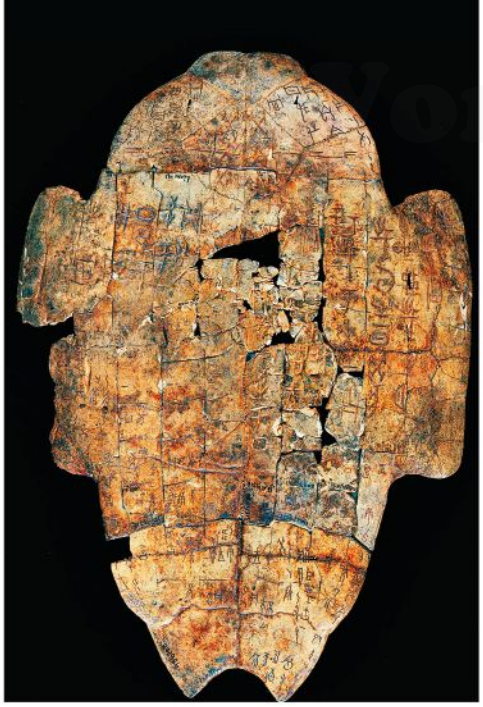
This fear of comets inspired the Chinese to catalog them. Historical texts contain details such as the date of a comet's first appearance, the constellations through which it moved, its characteristics, and the date of its final visibility. Although this all would prove valuable to future astronomers, the Chinese were working in the name of astrology, tying celestial to earthly events, especially wars, plagues, and the deaths of rulers.

Science versus superstition

The ancient Greeks were first to try to explain comets scientifically. The mathematician Pythagoras (ca. 570–495 B.C.), for instance, said only one comet existed. This object, he thought, was a planet in a circular orbit that occasionally brought it into view near the horizon. Philosophers Anaxagoras (ca. 500–428 B.C.) and Democritus (ca. 460–370 B.C.) said comets were close conjunctions of planets. Astronomer Hippocrates of Chios (ca. 470–410 B.C.) believed, like his contemporaries, that comets were planets, but he said the tails were moisture drawn from Earth to comets and reflecting sunlight.

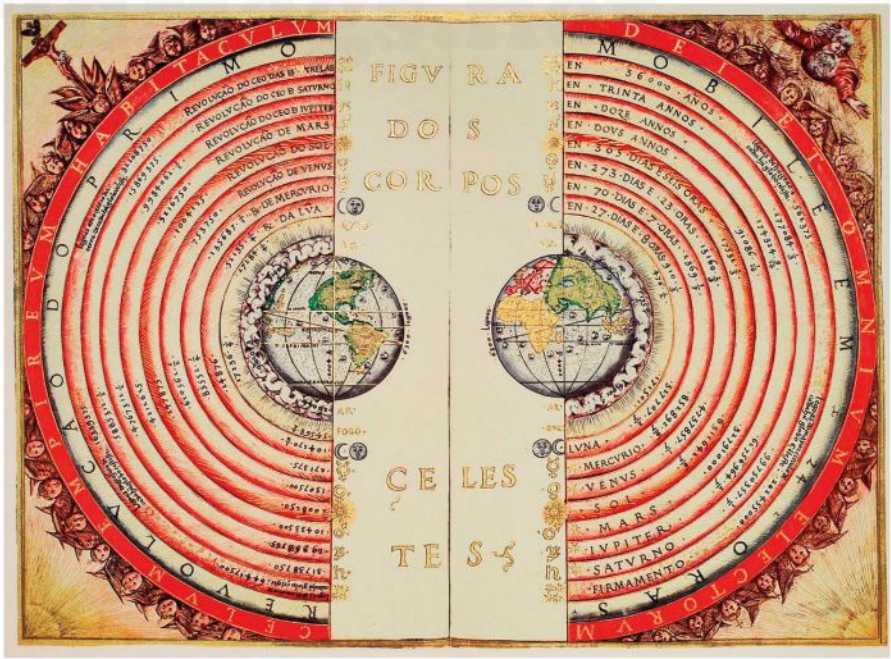
Aristotle (384–322 B.C.), however, did not care for any of these theories. He believed the heavens were perfect, with the planets

WorldMags.net



MUSEUM OF THE INSTITUTE OF HISTORY AND PHILOLOGY/ACADEMIA SINICA

The earliest recorded observations of comets are inscribed on bones and shells dating back from the 16th to 11th centuries B.C. The Chinese wrote detailed descriptions of comets' positions, shapes, and visible lifespans to determine how the heavenly visitors negatively affected the course of history.



Aristotle believed comets were atmospheric phenomena, an idea that reigned for 2,000 years despite the evidence against it. The philosopher thought of the universe as it appears above in "Figure of the Heavenly Bodies" (1568). A comet in a highly elliptical orbit did not fit within this worldview.

BARTOLOMEU VELHO

moving in circular orbits along the ecliptic, the yearly path the Sun traces across our sky. Comets were not planets, he said. They could materialize *anywhere* in the sky, and planetary conjunctions didn't always result in comets. Aristotle suggested that exhalations rose from Earth into the atmosphere, where they ignited. "If it extends equally in all directions," he said, "it is called a comet or long-haired star, if it extends lengthwise only it is called a bearded star."

A few other Greek and Roman philosophers offered competing theories during the next 400 years. Seneca (4 B.C.–A.D. 65), for example, pointed out that wind did not affect comets, which therefore could not be in the atmosphere. But so respected was Aristotle that his view, though groundless, held sway for some 2,000 years.

With the Aristotelian views entrenched, philosophers hardly debated what comets were and instead discussed what they represented. Many people, including the Roman poet Virgil (70–19 B.C.), believed comets were warnings. Upon the death of Julius Caesar (44 B.C.), Virgil wrote, "Never did fatal comets shine more often." The Greco-Roman astronomer Ptolemy (ca. A.D. 100–170) agreed with Aristotle that comets were earthly phenomena and with Virgil that they were portents. In his astrological work, *Tetrabiblos*, he said that comets' positions and orientations "point out the regions or places liable to be affected by the events which they threaten; and the form of the signs indicates the quality and nature of those events, as well as the genus, class, or kind, on which the effect will fall."

Sky scapegoat

During the next several centuries, people continued to deem significant comets responsible for negative events, and scientists of the age made few rebuttals. Several Roman writers said the comet of 12 B.C. (Halley's Comet) marked the death of General Marcus Vipsanius Agrippa. Next, the comet of A.D. 54 supposedly killed the Roman emperor Claudius Caesar. The subsequent appearance of Comet Halley in A.D. 66 foretold Jerusalem's destruction in A.D. 70, while another visit from Halley in 451 announced the death of Attila the Hun in 453. A comet in 565 forecast Byzantine emperor Justinian the Great's demise that year. And the *Nuremberg Chronicle* even blamed Halley's presence in 684 for three months of heavy rain and lightning that led to the deaths of people, animals, and crops.

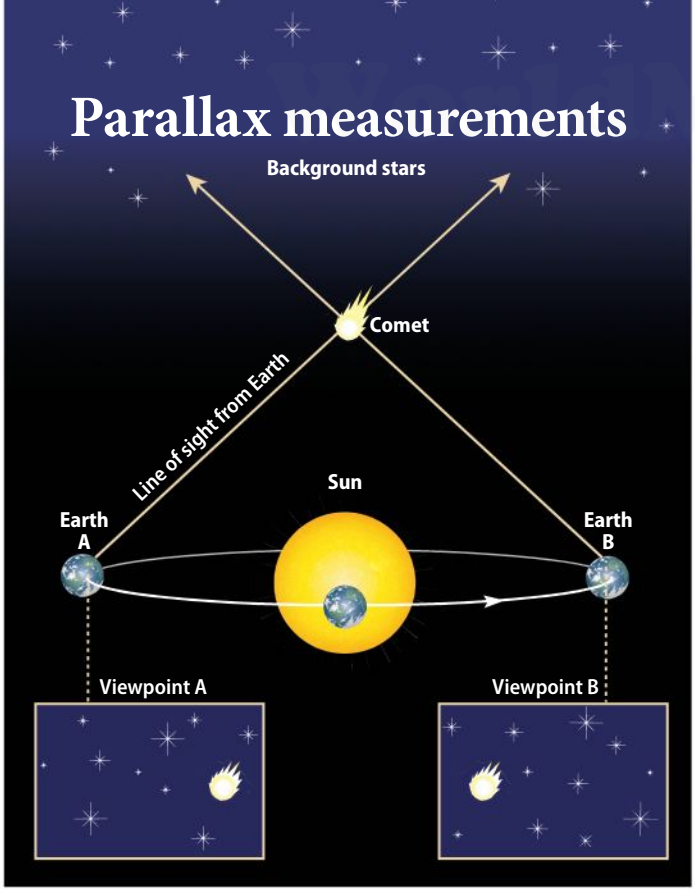
Perhaps the most noted cometary appearance of the Middle Ages was Comet Halley's in 1066. It popped up April 1 and remained visible until June 7. The Chinese meticulously described its movement, while the Italian text *Ex Regula Canonicorum* likened it to "an eclipsed moon" whose tail "rose like smoke halfway to the zenith." The famous Bayeux Tapestry illustrates the events leading up to the Norman conquest of England later in 1066, depicting the comet as a bad omen for King Harold. It appeared almost three months after he became king, and he died at the Battle of Hastings in October of that year. Chroniclers drew a link between Halley's presence and Harold's demise, a negative astrological viewpoint the likes of which continued during the next centuries as bright comets came and went and bad events continued to transpire on Earth.

The superstitious views of this epoch were unaffected by an apparent sungrazing comet — the Great Comet of 1106 (X/1106 C1) — whose arrival did not correspond to a major earthly upheaval. The comet was visible in broad daylight about a degree from the Sun on



ASTRONOMICUM CAESAREUM

In the late 13th century, Peter of Limoges used a torquetum, illustrated here, to measure the position of the Comet of 1299 (C/1299 B1). A user could adjust this instrument's settings to account for latitude and date and then measure a celestial object's altitude against a plumb line.



By observing how a nearby object's position against a background appears to change with the location of the observer, astronomers can determine how far away that object is. The more the background changes, the higher the "parallax" is and the closer the object. Georg von Peuerbach first used parallax to attempt to find the distance to a comet in the 15th century. *ASTRONOMY:* ROEN KELLY

February 2, 1106, and had moved to the western sky by February 10. Once again, the Chinese, who were meticulous but only interested in astrological thought, provided most of the details. The Armenian text *Chronicle*, which author Matheos Urhayetzi finished around 1137, said, "An awful, big and amazing comet appeared, which frightened those who saw it. Wise people said that it is a king sign, and that this year a king should be born who will conquer all of mankind." Nothing came of this prognostication.

Some semblance of scientific thought began to return in the 13th century. Aegidius of Lessines (ca. 1230–1304) made observations of the Great Comet of 1264 (C/1264 N1), reporting that it was first in the evening sky but as the days passed dropped into twilight and disappeared. He said the same comet then appeared in the early morning sky. As simple as the inference may seem, Aegidius' realization that the two sightings were a single comet was revelatory.

But pseudoscience was still winning the battle against science. Peter of Limoges (died 1306) wrote a treatise on Comet C/1299 B1, providing the first measurements of position. He made them with a torquetum, a medieval astronomical instrument. Although he was scientific, Peter of Limoges said Venus and Jupiter seemed to be influencing the comet, which "may mitigate the ill effects of the comet, or God may show mercy, if we live justly."

While Peter of Limoges may have taken observation a step forward, interpretation remained firmly in its backward place, as writings about Comet C/1402 D1 show. It arrived in the sky in early February 1402 and appeared over Europe and Asia. It moved to the western sky, displaying a tail that curved toward the zenith. The Welsh text *Chronicle of Adam of Usk* described the comet as



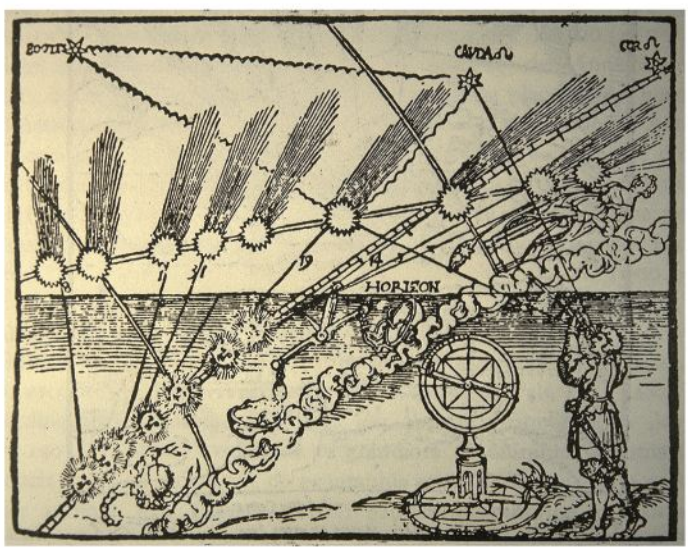
Tycho Brahe, whose observatory is illustrated on this page from a 17th-century atlas of Amsterdam, was the first to accurately measure the parallax of a comet, prove that it was far from Earth's atmosphere, and suggest that it was in an elliptical orbit around the Sun. WILLIAM BLAEU

"dreadful" and said it "forecast the death of the duke of Milan," providing no scientific input. Although astronomers made more analytical observations as time went on, the myth that comets possessed undue influence over Earth persisted.

Back to science class

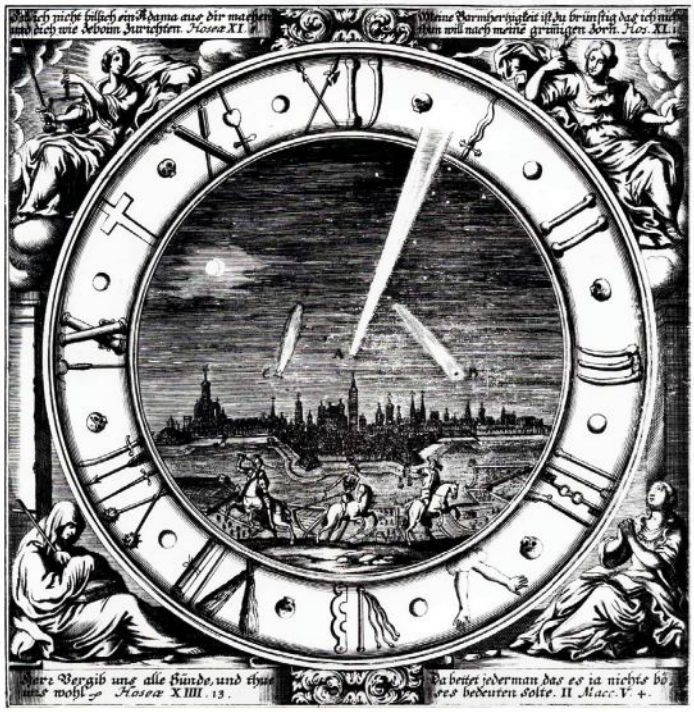
During the 15th century, two observers attempted to determine the distances to comets. Austrian astronomer Georg von Peuerbach (1423–1461) measured a comet's parallax, or how much the background behind it changed when he observed it from different locations. The more the background changes, the higher the parallax is and the closer the object. Two position measurements separated by several hours allowed Peuerbach to calculate the distance to Comet Halley (1456), which many thought was a "heavenly comment" on Constantinople's fall in 1453. His measurements incorrectly indicated the comet was in the atmosphere, as did those of his student Regiomontanus (1436–1476). He measured the parallax of Comet C/1471 Y1 and found the comet to be nine Earth radii away, a distance he thought placed it in the atmosphere. People continued to perceive comets to be Earth-centered phenomena.

The next big breakthrough relied on observation but did not prove comets were in space. Peter Apian (1495–1552) outlined the motion of the Comet of 1531, which happened to be another return of Halley. His graphic was the first to illustrate how a comet's tail always points away from the Sun.

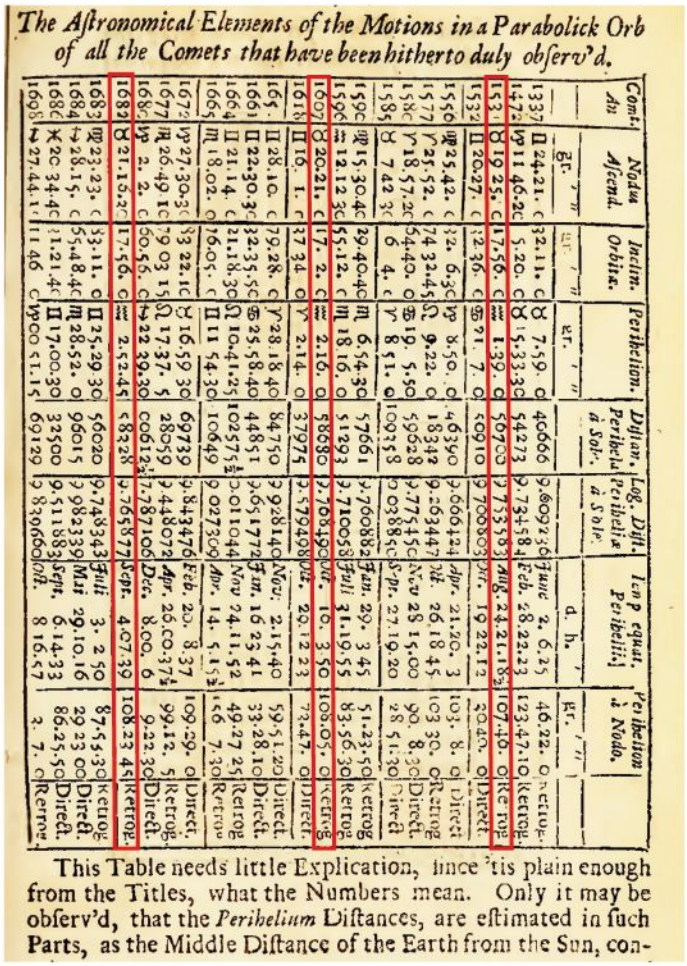


Peter Apian used a torquetum to measure Comet Halley's position at various points during 1531, making him the first to demonstrate that a comet's tail always points away from the Sun. THE GALILEO PROJECT

WorldMags.net



Three comets appeared in a three-year span between 1680 and 1683. This illustration shows the skyline of Augsburg, Germany, lorded over by the comets, drawn to scale. NASA/JPL



The Astronomical Elements of the Motions in a Parabolick Orb of all the Comets that have been hitherto duly obſerv'd.

This Table needs little Explication, ſince 'tis plain enough from the Titles, what the Numbers mean. Only it may be obſerv'd, that the *Perihelium* Diſtances, are eſtimated in ſuch Parts, as the Middle Diſtance of the Earth from the Sun, con-

Edmond Halley noticed that several comets had identical dynamics and suggested in *A synopsis of the astronomy of comets* that the same comet was appearing repeatedly. Three of its apparitions are outlined in red above. OPENLIBRARY

However, the Aristotelian view even had a hold on the likes of Nicolas Copernicus (1473–1543), who was the first to take astronomy's focus from our planet to our star. Despite asserting that the Sun is the center of the solar system, he, too, believed comets formed in Earth's atmosphere. He wrote, "The highest region of the air follows the celestial motion. This is demonstrated by those stars that suddenly appear — I mean those stars that the Greeks called cometae or poganiae. The highest region is considered their place of generation, and just like other stars they also rise and set."

The comet that almost became a game-changer for the Aristotelian view was Comet C/1577 V1, first observed in Peru on November 2. One week later, it had become visible throughout Europe and Asia, sporting a tail at least 50° long. Some European parallax measurements indicated the comet was in the atmosphere, while others deemed it to be outside. The opinion of Danish astronomer Tycho Brahe (1546–1601), however, carried the most weight.

With the same instruments that he used to measure stars' motions, Brahe measured the comet's parallax. The comet did not move much relative to the stars, and Brahe concluded that it was at least 230 Earth radii away, beyond the Moon's orbit. In his treatise, Brahe dismissed Aristotle's ideas and suggested that comets move in elliptical orbits around the Sun. Sadly, this logic seems overshadowed by Brahe's statement that the comet would "spew its venom" over the lands toward which the tail was pointed.

Despite Brahe's great accomplishment, another famous astronomer would cast doubt on his findings and set cometary astronomy back several more decades. That person was Galileo Galilei (1564–1642), who wrote in his 1623 book *The Assayer*, "A comet is not one of the wandering stars which become visible in a manner similar to that of some planet." He suggested that comets were vapors rising from Earth's atmosphere or perhaps an optical illusion and completely dismissed Brahe's parallax measurements.

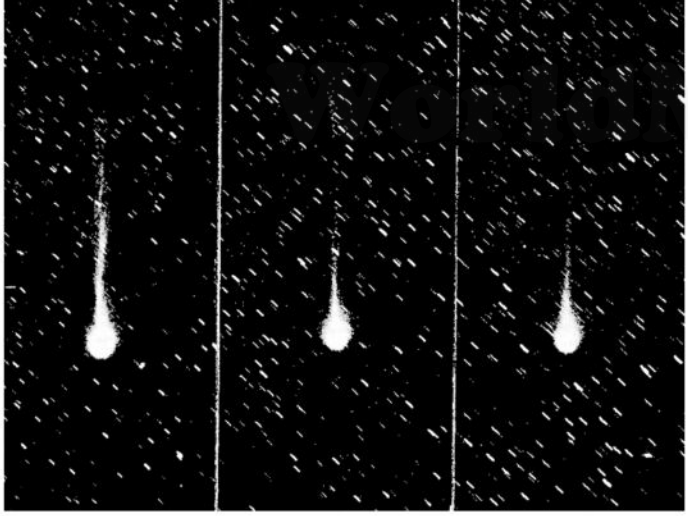
As the 17th century progressed, the Great Comet of 1664 (C/1664 W1), which displayed a tail nearly 30° long, entered the scene from November 1664 to March 1665. In Korea, the sight prompted the king to double security at all ports and "caused fortresses to be furnished with provision, and warlike stores," according to an account by Henry Hamel, the secretary aboard a Dutch ship. People in London also were worried, especially when the first signs of the bubonic plague, which ultimately killed 100,000 people in that city, occurred when the comet was bright. As if one comet was not enough, another bright one emerged at the end of March 1665 and displayed a tail nearly 20° long.

Analyze this

The Great Comet of 1680 (C/1680 V1) was the first to be discovered through a telescope. The German astronomer Gottfried Kirch (1639–1710) was about to measure a star's position when he moved the telescope and found "a sort of nebulous spot, of an uncommon appearance." He continued to follow the comet, which later brightened into a naked-eye object. In 1687, Isaac Newton (1642–1727) calculated its motion — the first person to determine any comet's orbit. Its path proved once and for all that comets did not occur in the atmosphere, and the Aristotelian view was finally put to rest — more than 2,000 years after he first suggested it.

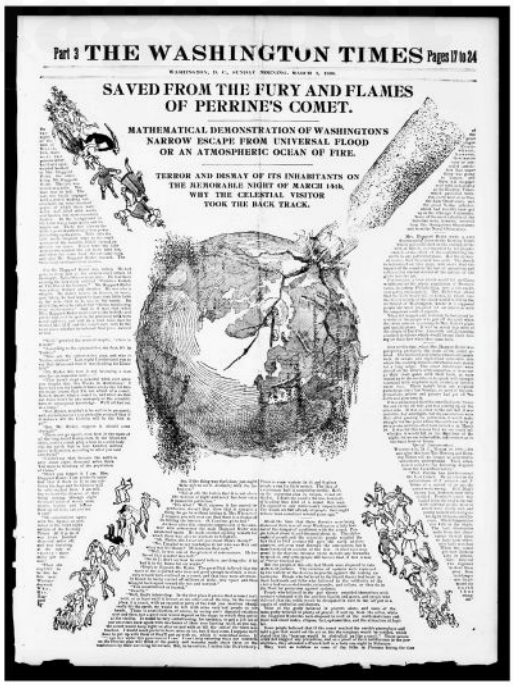
Edmond Halley (1656–1742) wrote to Newton and suggested he calculate orbits for other comets. But Newton did not oblige, so Halley began the task himself. By the late 1690s, Halley had calculated the orbits of 24 comets that had appeared between 1337 and 1698. Most importantly, he noted that the orbits of those in 1531,

WorldMags.net



NASA ASTROPHYSICS DATA SYSTEM/ASTRONOMICAL SOCIETY OF THE PACIFIC

The Astronomical Society of the Pacific published images that E. F. Coddington and H. K. Palmer took of Comet Swift (C/1899 E1), which Lewis Swift had discovered in March 1899. Some predicted this comet would collide with Earth.



Part 3 THE WASHINGTON TIMES Pages 17 to 24

SAVED FROM THE FURY AND FLAMES OF PERRINE'S COMET.

MATHEMATICAL DEMONSTRATION OF WASHINGTON'S NARROW ESCAPE FROM UNIVERSAL FLOOD OR AN ATMOSPHERIC OCEAN OF FIRE.

TERROR AND DISMAY OF ITS INHABITANTS ON THE MEMORABLE NIGHT OF MARCH 14th. WHY THE CELESTIAL VISITOR TOOK THE BACK TRACK.

In the late 1800s, some predicted that three separate comets would crash into Earth. These forecasts garnered considerable media attention but came to naught. LIBRARY OF CONGRESS/CHRONICLING AMERICA

1607, and 1682 were nearly identical, suggesting that this was the same object. The object came to be known as "Halley's Comet."

Superstitions surrounding comets seemed to subside after Halley published his paper. Other scientists carried the analytical torch. German astronomer Johann Encke (1791–1865), stepping in Halley's footprints, was next to predict a periodic comet's return. A comet that appeared in 1818 (2P/Encke) would pop up again in just 3.3 years, he correctly predicted.

But there's more to comets than their motions. Astronomers still needed to find out what comets *were*. German philosopher Immanuel Kant (1724–1804) paused his studies of morality to suggest that the cometary material vaporized easily, leading to increasing brightness as the objects approached the Sun. German researchers Heinrich Olbers (1758–1840) and Friedrich Bessel (1784–1846) posited that the tails were made of solid particles that a repulsive force pushed away from the Sun. Later, in 1900, Svante Arrehnius (1859–1927) identified the particle pushback as radiation pressure. In the 1860s, Italian astronomer Giovanni Schiaparelli (1835–1910) demonstrated that the solid debris streaming from comets related to meteor showers when he noted that the Perseid meteor stream and Comet 109P/Swift-Tuttle followed nearly the same orbit.

The 18th and 19th centuries pushed comet science forward, and the fearmongering of prior centuries was largely absent. The only scare tactics during the 1700s and 1800s were localized proclamations, such as those by Baptist preacher William Miller (1782–1849). Beginning in 1831, Miller and his followers, known as the "Millerites," preached that the world would end in 1843. The Great March Comet of 1843 (C/1843 D1) happened to appear late that February, visible midday though less than ½° from the Sun, giving Miller attention from previous nonbelievers, but not ending the world.

Yellow journalism

Still, perhaps as a way to increase readership, newspapers in the United States tried to generate fear. The *Daily National Intelligencer* of Washington, D.C., ran a story March 17, 1857, stating that the French astronomer Jacques Babinet had predicted the collision of a comet with Earth on June 13. The story spread across the nation. In the March 30 edition of the *New York Herald*, however, Babinet denied making the prediction: "Those who are killed by comets merely die of terror, stupidity, and ignorance."

Shortly after the Civil War began in the United States in early 1861, the bright Comet C/1861 J1 blazed through the sky, displaying a tail nearly 100° long. The July 2, 1861, edition of the *Wisconsin Daily Patriot* stated that many people feared the comet "forboded evil" since it lit up during the time of war. Fortunately, *The Picayune* of New Orleans published a more sane statement: "We imagine that the appearance of a comet in our heavens no more necessarily betokens war, than peace."

During the remainder of the 19th century, newspapers published stories that predicted further collisions between comets and Earth during 1872, 1892, and 1899. The first was a rumor, the second a misidentification, and the third a result of bad mathematics. A number of bright comets visited during this same period, including the Great September Comet of 1882 (C/1882 R1), which became visible in broad daylight. Interestingly, no one made prognostications of disaster for this comet. But just when it seemed that humanity was not to be fooled again by predictions of doom, along came Comet Halley in 1910.

Astronomers already had predicted that this would be an exceptional apparition, and papers began spreading the news that Earth would pass through the comet's tail. In a classic example of how scientific information can be twisted, *The New York Times* reported in 1910 that cyanogen was a common cometary component and "a very deadly poison." Although astronomers said there was nothing to worry about, some panicked anyway. Entrepreneurs came to their rescue and sold "anti-comet pills" and comet inhalers to protect people from the gas. The products sold quite well, and no one who used these products died. But, then again, no one else died as a result of the comet, either.

Despite numerous bright comets during the next decades, none generated public fear, though the two world wars easily and dubiously could have been linked to comets. Instead, using bigger and better telescopes and eventually photography, astronomers developed an understanding of what comets actually are. People no longer took the astrological implications of comets as seriously as they had in ancient and medieval times. The majority of the public finally understood that exciting comets should be enjoyed and not feared.

WorldMags.net

MARTIN RATCLIFFE and **ALISTER LING** describe the solar system's changing landscape as it appears in Earth's sky.

Visible to the naked eye
Visible with binoculars
Visible with a telescope

November 2013: ISON at its brightest



On November 3, early risers along the East Coast of the United States and Canada can witness a partial eclipse of the Sun. HINRICH BÄSEMANN

The month of the comet has finally arrived. The long-awaited predawn appearance of Comet ISON (C/2012 S1), potentially one of the brightest such objects in many decades, no doubt will leave many observers bleary-eyed as they go about their normal daytime tasks.

The solar system's planets surely will take a backseat to the comet, but they also offer plenty to celebrate. Mercury enjoys its best morning appearance of 2013. It passes near both Saturn and ISON late this month. While Mars and Jupiter put on their best shows after midnight, Venus dominates the early evening sky. Finally, although the comet may win this month's grand prize for magnificence, a November 3 total solar eclipse in Africa has to rank a close second.

As darkness falls in November, **Venus** gleams low in the southwestern sky. It lies 47° east of the Sun on the 1st, its maximum elongation for this apparition. Yet the brilliant planet actually climbs higher in the evening sky as the month progresses.

Solar system geometry explains this apparent contradiction. The ecliptic — the apparent path of the Sun across the sky that the planets follow closely — makes a shallow angle to the western horizon after sunset in early autumn from mid-northern latitudes. Venus' elongation from the Sun thus translates more into distance along the horizon than altitude above it. The ecliptic's angle steepens sharply in late autumn, however, more than offsetting the planet's dwindling elongation.

On November 1, Venus stands 11° high an hour after sunset; by the 30th, it is 15° high. The planet brightens during November, too, from magnitude –4.5 to –4.8, so it grows even more prominent.

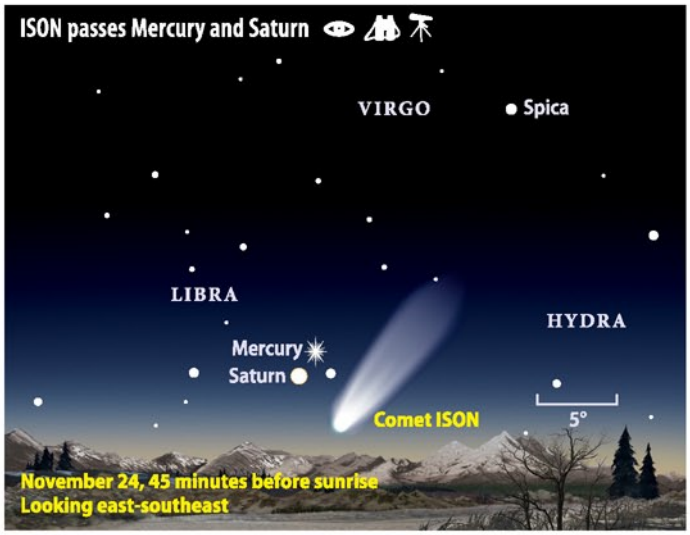
Venus spends the month among the background stars of Sagittarius. On November 6, a waxing crescent Moon passes 8° north of the planet. Look midway between this attractive pair to find the Lagoon (M8) and Trifid (M20) nebulae. On the 13th, Venus slides 3° south of globular star cluster M22. Binoculars will show these deep-sky objects on haze-free evenings once the sky darkens sufficiently.

With Venus passing through greatest eastern elongation, its appearance through a telescope changes rapidly. On November 1, it appears 25" across and half-lit. By month's end, the planet spans 37" and sunlight illuminates only 31 percent of its disk.

Once the evening sky grows completely dark, **Neptune** makes a tempting target. The distant world then lies due south and nearly halfway from the horizon to the zenith. It lies in the central part of the constellation Aquarius, between the 5th-magnitude stars Sigma (σ) and 38 Aquarii. Neptune glows at magnitude 7.9, however, so you will need to study this region in some detail.

The planet spends all of November on the line joining these two stars, approximately 3° west of Sigma and 2° east of 38. To confirm its identity, view it through a telescope at medium to high magnification. Every star will appear as a point of light, but Neptune will show a blue-gray disk measuring 2.3" across.

The best time to view **Uranus** is when it lies highest in the south, around 9 P.M. local time in mid-November.



Comet ISON should be a spectacle when it passes near Mercury and Saturn in morning twilight November 24. *ASTRONOMY:* ROEN KELLY

Martin Ratcliffe *provides planetarium development for Sky-Skan, Inc., from his home in Wichita, Kansas. Meteorologist* **Alister Ling** *works for Environment Canada in Edmonton, Alberta.*

WorldMags.net

RISING**MOON**

Fractured but fabulous Fracastorius

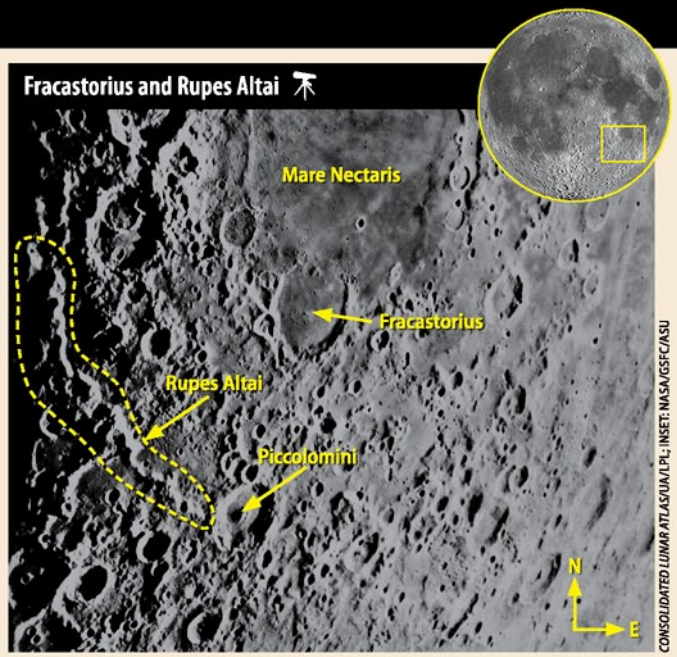
Although it might not seem so at times, there's more to lunar history than fresh impacts creating new craters and erasing older ones. The massive impact that carved out Mare Nectaris (Sea of Nectar) about 4 billion years ago affected the face of cratering history for millions of years to come. This mare lies just south of the lunar equator and becomes fully illuminated November 8, a day before First Quarter phase.

View this area through your telescope, and a bright white arc will catch your eye. Rupes Altai (Altai Scarp) appears to be centered perfectly on Nectaris, and that's no accident. This scarp is a remnant of the fourth rim of the Nectaris multiring basin.

The younger crater Piccolomini dangles on the end of the scarp like an earring. This crater spans 55 miles and sports a complex central peak. Examine Piccolomini's walls, and you'll see that lots of debris has slumped into the cavity, mimicking the effect you get by digging a hole in wet sand. The crater's south side has much more material thanks to the unstable terrain generated by the scarp's formation.

To the north of Piccolomini lies Fracastorius, a crater of intermediate age that's missing its northern rim. Like water, molten lava finds its own level, so it's easy to see that Fracastorius tilts down to the north. Lunar geologists have deduced that before this final flood, a smaller surge of lava rose up through cracks in Nectaris' floor and then solidified, sinking the central part and causing the surrounding terrain to tilt down toward the sea's middle. By the way, Fracastorius did not get its name because the crater appears fractured. Instead, it honors the 16th-century Italian astronomer Girolamo Fracastoro.

If you view on November 7, you can watch the peaks of Rupes Altai and Piccolomini pop into view one by one as the evening progresses. With the Sun rising slowly over this lunar terrain, high points to the west and lower points to the east light up with each passing hour.



The large crater Fracastorius sits in the southern part of Mare Nectaris; Rupes Altai marks the outer rim of this vast "sea."

The magnitude 5.8 planet travels slowly westward in a rather barren region along the border between Pisces and Cetus. To find the distant orb, scan 6° southwest of magnitude 4.4 Delta (δ) Piscium with your binoculars. The two brightest objects in this area are Uranus and the equally bright star 44 Psc, which lies some 2° farther from Delta. To confirm your sighting, view the object through a telescope at medium magnification. Uranus will show a 3.6"-diameter disk with a distinct blue-green color.

On mid-November evenings, the familiar shape of Orion the Hunter clears the eastern horizon by around 9 P.M. local time. **Jupiter** and its host constellation, Gemini the Twins, come to prominence to the left of Orion less

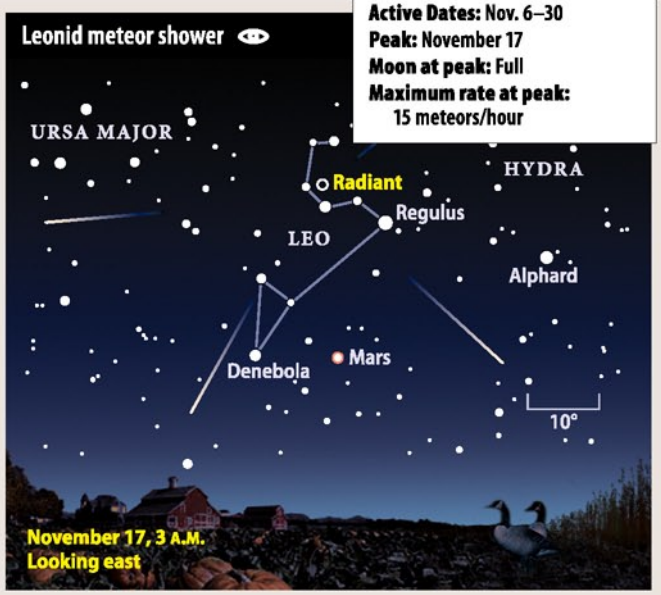
— *Continued on page 42*

METEORWATCH

The Moon mutes the Lion's roar

The annual Leonid meteor shower peaks before dawn November 17. In a normal year, skygazers can expect to see up to 15 meteors per hour under a clear, dark sky. Unfortunately, 2013 delivers little darkness because the Moon is Full the same morning.

Your best bet is to observe in the hour before dawn and position yourself so trees or buildings block the Moon. One favorable note: Leonid meteors hit Earth's atmosphere at the breakneck speed of 44 miles per second, so they produce more fireballs than most meteor showers.



The Full Moon on November 17 diminishes the peak of this year's Leonid meteor shower. *ASTRONOMY:* KELLIE JAEGER

OBSERVING HIGHLIGHT Comet ISON (C/2012 S1) brightens dramatically in the morning sky as it approaches perihelion in late November.

WorldMags.net

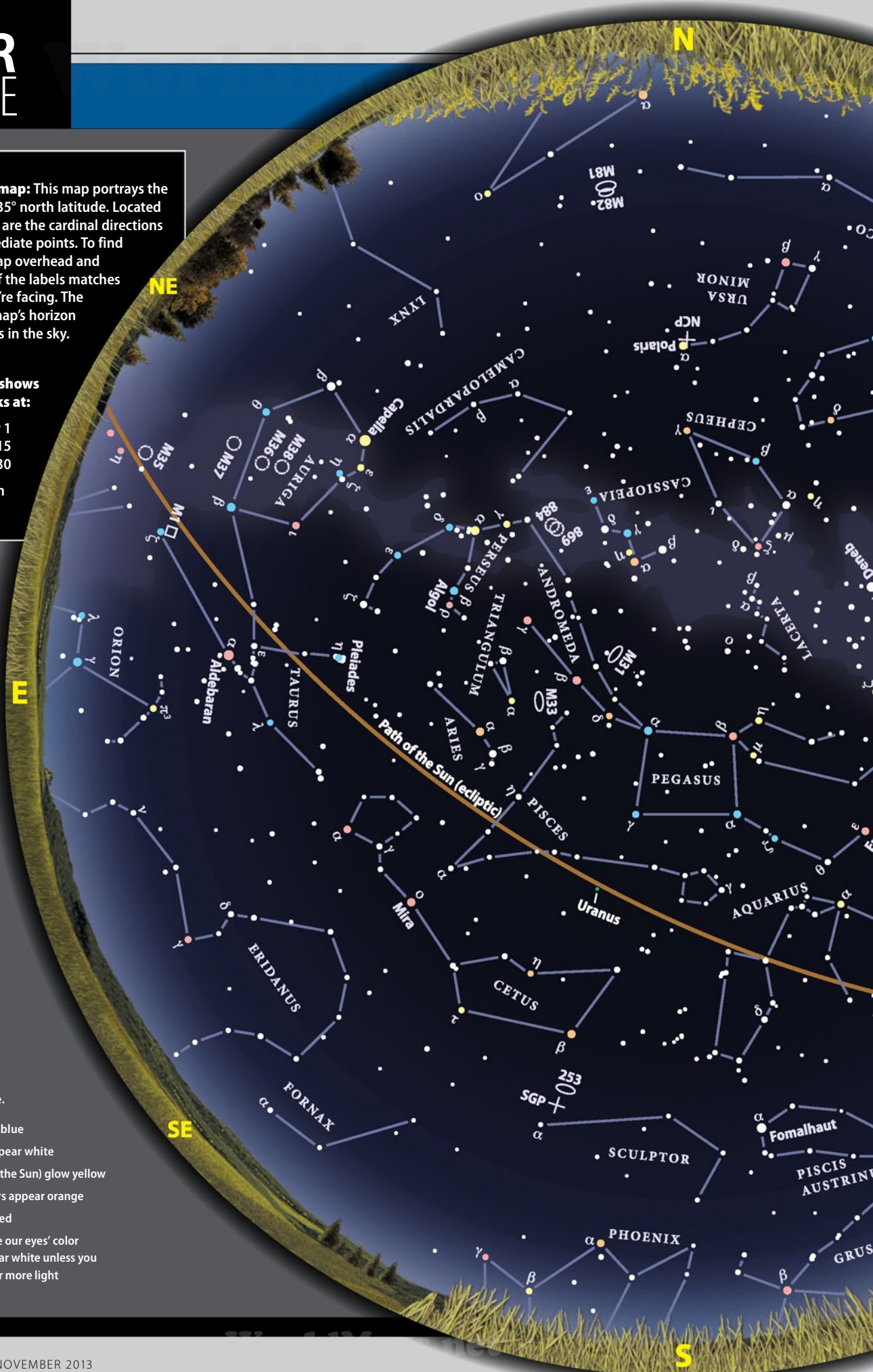
STAR DOME

How to use this map: This map portrays the sky as seen near 35° north latitude. Located inside the border are the cardinal directions and their intermediate points. To find stars, hold the map overhead and orient it so one of the labels matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

The all-sky map shows how the sky looks at:

10 P.M. November 1
8 P.M. November 15
7 P.M. November 30

Planets are shown at midmonth



STAR MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

STAR COLORS

A star's color depends on its surface temperature.

- The hottest stars shine blue
- Slightly cooler stars appear white
- Intermediate stars (like the Sun) glow yellow
- Lower-temperature stars appear orange
- The coolest stars glow red
- Fainter stars can't excite our eyes' color receptors, so they appear white unless you use optical aid to gather more light



NOVEMBER 2013

Note: Moon phases in the calendar vary in size due to the distance from Earth and are shown at 0h Universal Time.

SUN.	MON.	TUES.	WED.	THURS.	FRI.	SAT.
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

ILLUSTRATIONS BY *ASTRONOMY*: ROEN KELLY

Calendar of events

1 Venus is at greatest eastern elongation (47°), 4 A.M. EDT

Mercury is in inferior conjunction, 4 P.M. EDT

2 The Moon passes 0.8° north of Spica, 3 A.M. EDT

3 New Moon occurs at 7:50 A.M. EST

SPECIAL OBSERVING DATE

3 A total solar eclipse occurs along a narrow path that cuts across the Atlantic Ocean and equatorial Africa.

6 The Moon is at perigee (227,025 miles from Earth), 4:22 A.M. EST

Saturn is in conjunction with the Sun, 7 A.M. EST

The Moon passes 8° north of Venus, 8 P.M. EST

7 Jupiter is stationary, 2 A.M. EST

10 First Quarter Moon occurs at 12:57 A.M. EST

Mercury is stationary, 9 A.M. EST

11 The Moon passes 6° north of Neptune, 6 A.M. EST

13 Neptune is stationary, 5 P.M. EST

The Moon passes 3° north of Uranus, 10 P.M. EST

16 Asteroid Kleopatra is at opposition, 8 A.M. EST

17 Full Moon occurs at 10:16 A.M. EST

Leonid meteor shower peaks

Mercury is at greatest western elongation (19°), 10 P.M. EST

21 The Moon passes 5° south of Jupiter, midnight EST

22 The Moon is at apogee (251,931 miles from Earth), 4:49 A.M. EST

25 Last Quarter Moon occurs at 2:28 P.M. EST

Mercury passes 0.3° south of Saturn, 11 P.M. EST

27 The Moon passes 6° south of Mars, 11 A.M. EST

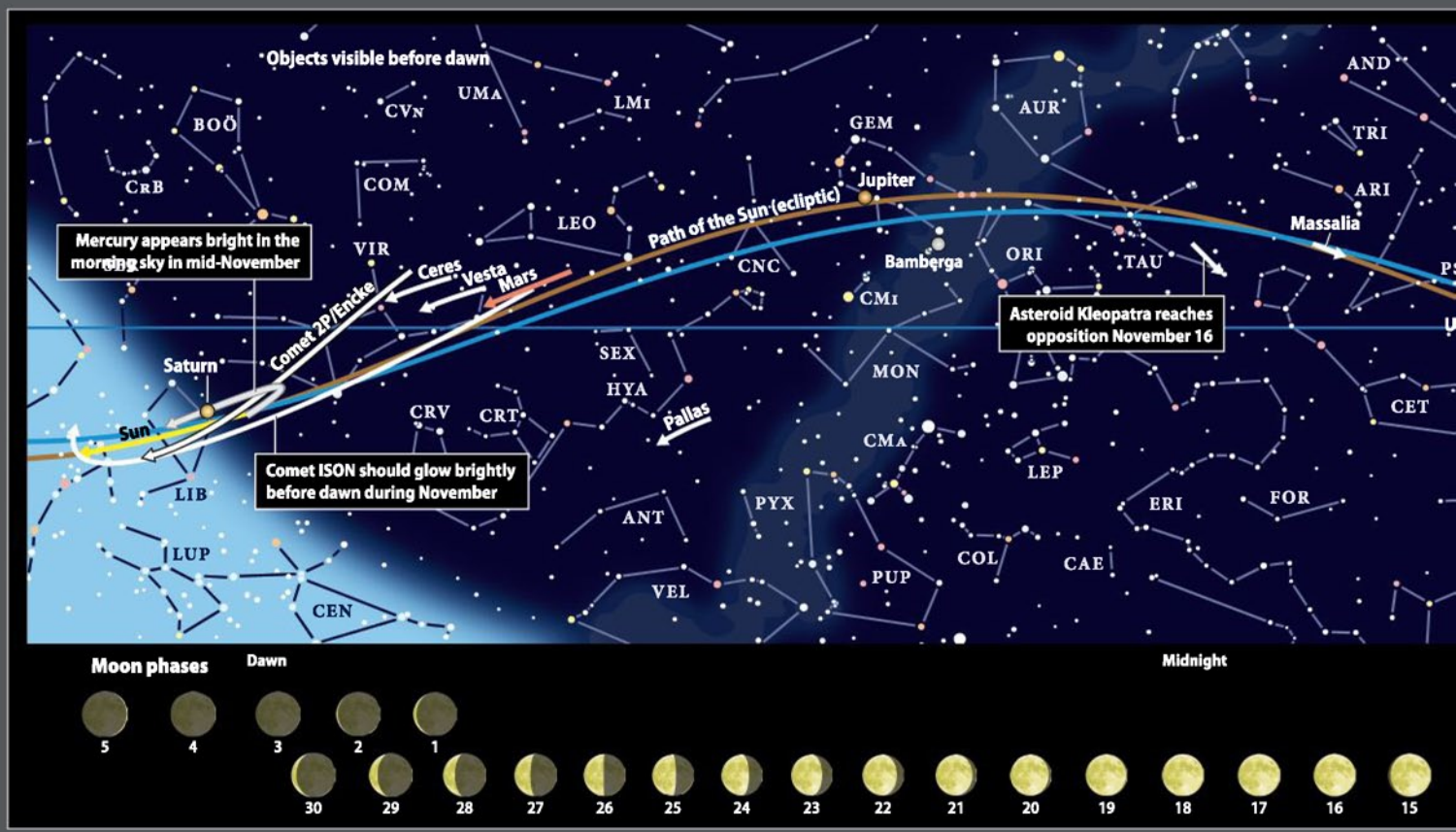
28 Comet ISON (C/2012 S1) reaches perihelion (1.157 million miles from the Sun), 2 P.M. EST

29 The Moon passes 0.9° north of Spica, noon EST

BEGINNERS: WATCH A VIDEO ABOUT HOW TO READ A STAR CHART AT www.Astronomy.com/starchart.

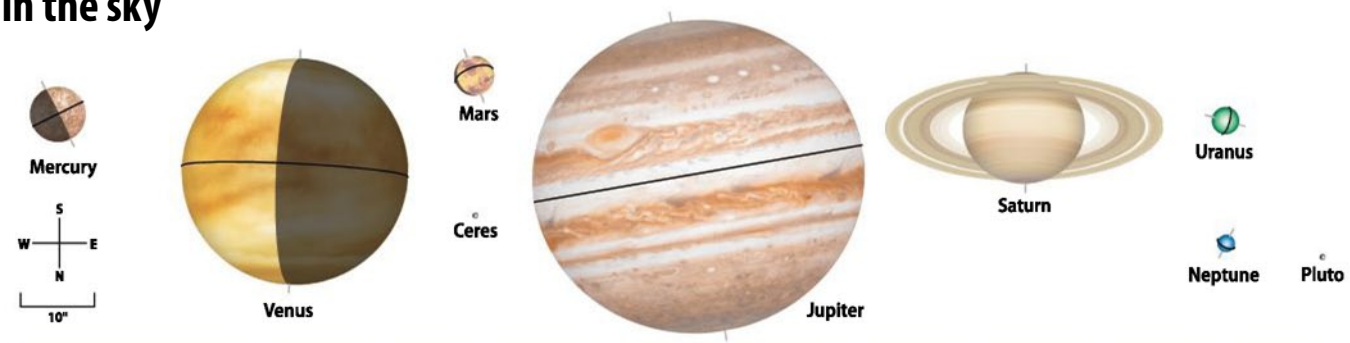
PATH OF THE PLANETS

The planets in November 2013



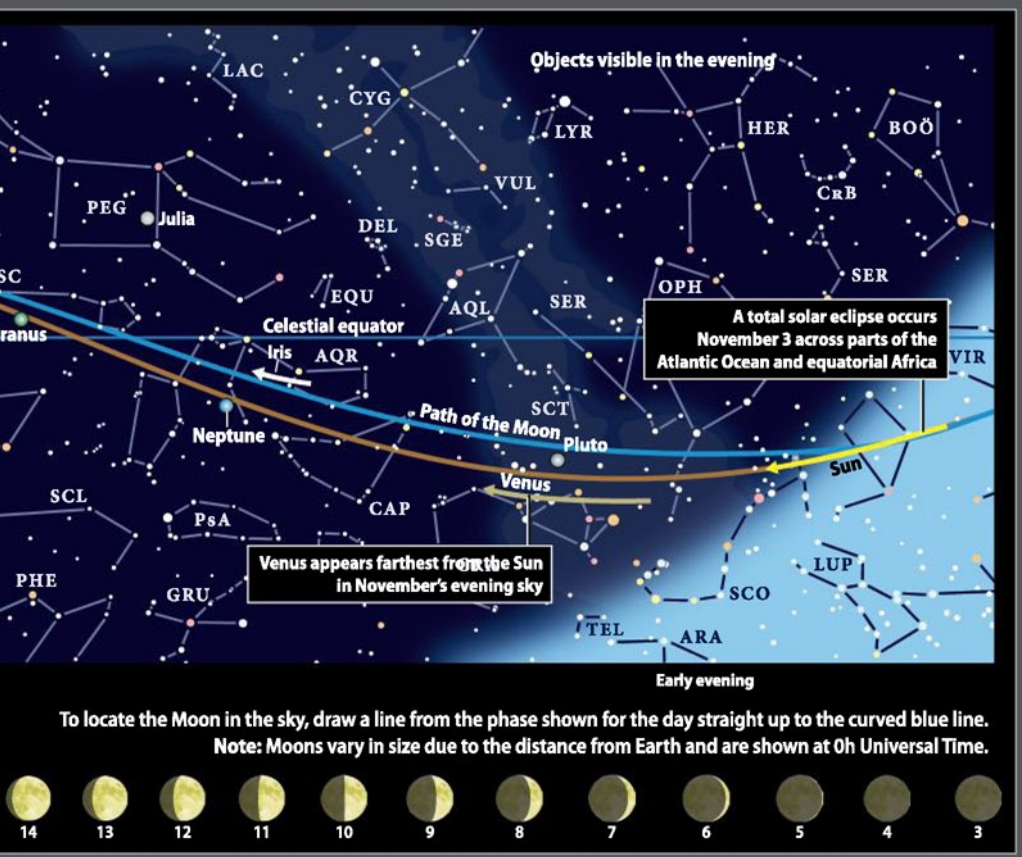
The planets in the sky

These illustrations show the size, phase, and orientation of each planet and the two brightest dwarf planets for the dates in the data table at bottom. South is at the top to match the view through a telescope.

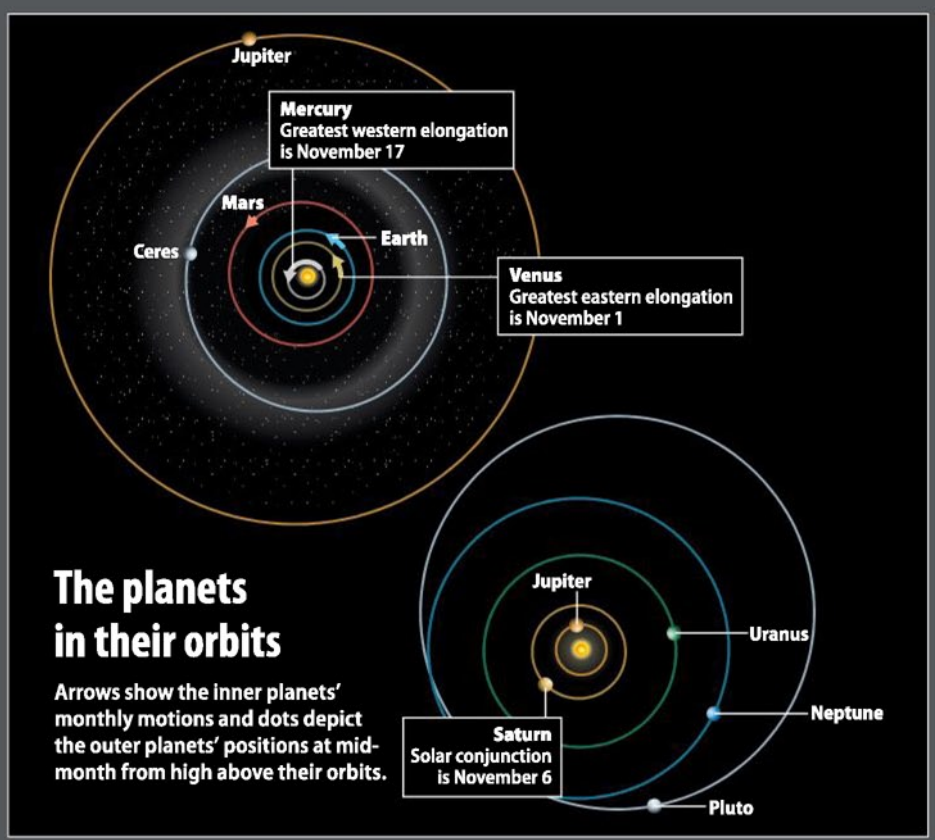


Planets	MERCURY	VENUS	MARS	CERES	JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
Date	Nov. 15	Nov. 15	Nov. 15	Nov. 15	Nov. 15	Nov. 30	Nov. 15	Nov. 15	Nov. 15
Magnitude	–0.4	–4.7	1.4	8.8	–2.5	0.6	5.8	7.9	14.2
Angular size	7.3"	29.6"	5.2"	0.4"	43.1"	15.4"	3.6"	2.3"	0.1"
Illumination	47%	42%	92%	98%	99%	100%	100%	100%	100%
Distance (AU) from Earth	0.918	0.564	1.806	3.108	4.577	10.788	19.311	29.797	33.210
Distance (AU) from Sun	0.322	0.725	1.654	2.563	5.175	9.873	20.038	29.981	32.544
Right ascension (2000.0)	14h09.3m	18h39.4m	11h16.7m	12h30.7m	7h27.5m	14h59.9m	0h33.6m	22h18.4m	18h40.7m
Declination (2000.0)	–10°34'	–26°51'	6°30'	6°10'	21°56'	–14°50'	2°51'	–11°16'	–20°15'

This map unfolds the entire night sky from sunset (at right) until sunrise (at left).
Arrows and colored dots show motions and locations of solar system objects during the month.



To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved blue line.
Note: Moons vary in size due to the distance from Earth and are shown at 0h Universal Time.

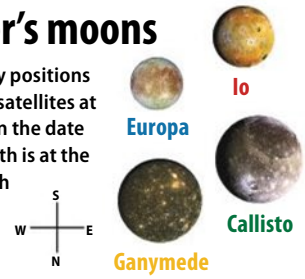


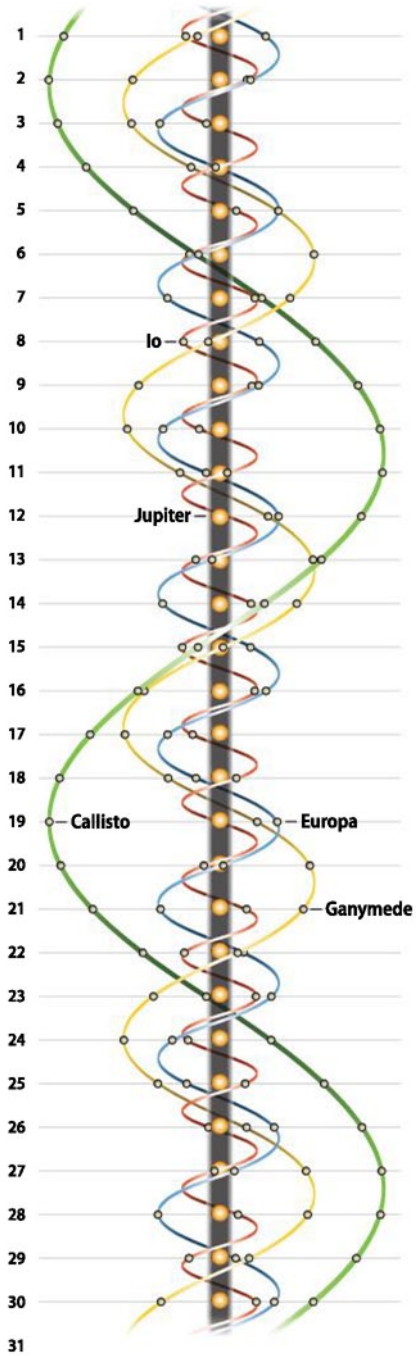
The planets in their orbits

Arrows show the inner planets' monthly motions and dots depict the outer planets' positions at mid-month from high above their orbits.

Jupiter's moons

Dots display positions of Galilean satellites at 4 A.M. EST on the date shown. South is at the top to match the view through a telescope.





ILLUSTRATIONS BY ASTRONOMY: ROEN KELLY

— Continued from page 37

WHEN TO VIEW THE PLANETS

EVENING SKY	MIDNIGHT	MORNING SKY
Venus (southwest)	Jupiter (east)	Mercury (east)
Uranus (southeast)	Uranus (southwest)	Mars (southeast)
Neptune (south)	Neptune (west)	Jupiter (southwest)
		Saturn (southeast)

than an hour later. The giant planet shines brilliantly at magnitude –2.5, so there's no mistaking it for any star. On the night of November 21/22, a waning gibbous Moon passes 5° south of Jupiter.

Although it might be tempting to observe Jupiter through a telescope as soon as it rises, better views await once it climbs higher. If you wait until 11 P.M. local time, the planet lies 30° high and should look magnificent. The best views will come when Jupiter passes nearly overhead in the early morning hours.

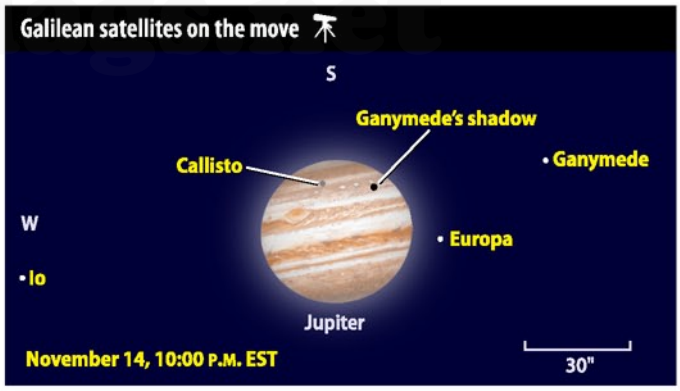
Earth's orbital motion carries us nearly 10 percent closer to Jupiter during November. For backyard observers, this means the giant planet's diameter grows by an equal amount, swelling from 41" to nearly 45".

How many belts and zones do you see in the planet's atmosphere? Most novices see two dark equatorial belts and a brighter zone between them. But with a bit of practice and patience, observers can discern an entire series of parallel bands. Turbulence at the boundaries between these features shows up as delicate wisps and swirls.

It doesn't take any experience to enjoy the dance moves of Jupiter's four bright moons. Io, Europa, Ganymede, and Callisto orbit with clockwork precision and often present intriguing alignments. Some of the best occur when a moon passes in front of Jupiter and casts its shadow onto the planet's cloud tops. With opposition and peak visibility now two months away, the geometry of the Sun, Earth, and Jupiter causes a satellite's shadow to transit Jupiter well before the satellite itself.

One of the best events this month favors observers east of the Rockies on the night of November 14/15. As soon as Jupiter rises, point your telescope at the planet's disk and look for the obvious contrast between Ganymede's black shadow and Callisto's grayish disk. Callisto remains silhouetted against the jovian clouds until 11:32 P.M. EST, while Ganymede's shadow lingers for nearly an hour longer (until 12:25 A.M. EST). Although Ganymede itself lies east of Jupiter during these proceedings, the solar system's largest moon executes its own three-hour transit starting at 1:42 A.M. EST.

Jupiter stands out during November because it's so bright. **Mars** stakes its claim to distinction through its



Jupiter's outermost large moon, Callisto, slides across the planet's cloud tops while Ganymede's shadow does the same November 14. *ASTRONOMY:* KELLIE JAEGER

COMETSEARCH

A double dose of comets at dawn

Before ISON peaks at the close of November, rise early and enjoy the pre-show during the month's first half. Observers normally would consider themselves lucky to see one nice binocular comet a year, and we reached that quota in the spring with PANSTARRS (C/2011 L4).

But now we have a simultaneous pair. Periodic comet 2P/Encke hangs low in the east two hours before sunrise a few binocular fields from Comet ISON (C/2012 S1). Both should brighten from 7th to 5th magnitude during November's first half, bringing them within easy range of binoculars from the country or a 4-inch scope from the suburbs.

Nice comets repay the effort of driving to a dark site, with their dusty tails appearing much longer and wider. Encke should show a fairly bright central core with a narrow fan extending westward. At 100x, its southern flank will be sharper thanks to the confining actions of the solar wind and radiation pressure. In contrast, ISON's dust tail should be broad because we are viewing it almost from the side.

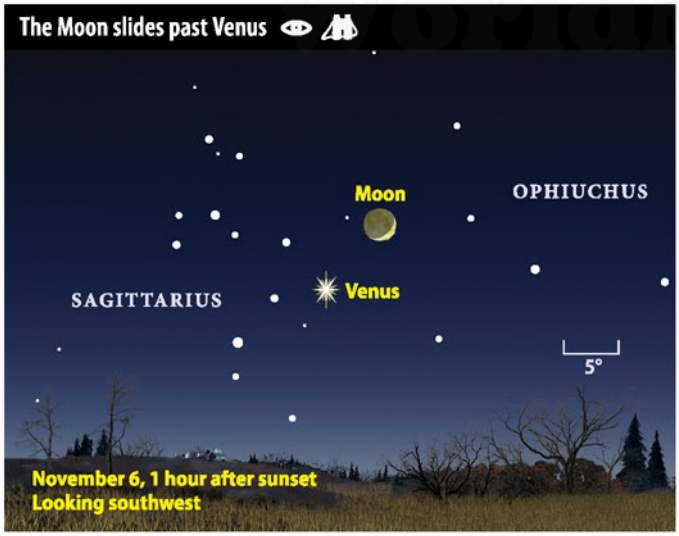
For visual observers, mid-November will be it for this apparition of Encke. Moonlight hits the morning sky thereafter, and the comet descends into an increasingly bright dawn sky. Its journey outbound from the Sun will be lost in our star's glare. Still, imagers likely will keep tracking this dirty snowball as a bonus while documenting ISON on its rise to fame.

Viewing ISON during daylight around the time of the comet's November 28 perihelion will be a thrill but also extremely dangerous, with the threat of accidental blindness and equipment damage. Only viewers in the Northern Hemisphere should attempt this observation. What you need to do is set up in the shadow of a building with a horizontal roofline running east-west. Do this within a half-hour of local noon, when the Sun travels a nearly horizontal path in the sky. Then scan just above the Sun's blocked position. If ISON brightens well beyond Venus' typical magnitude –4, you might just glimpse it.



Autumn's brightest comet glowed at 16th magnitude when the Gemini North Telescope captured it in early May. GEMINI OBSERVATORY/AURA

WorldMags.net



ASTRONOMY: KELLIE JAEGER

Venus appears farthest from the Sun in November's evening sky, but the highlight of its month comes on the 6th, when the Moon passes near.

color. The Red Planet's obvious ruddy glow clears the eastern horizon by 1:30 A.M. local time in mid-November. Shining at magnitude 1.4, it appears bright but not unusually so — a dozen or more stars exceed its intensity these November nights.

Mars begins the month in the constellation Leo the Lion, roughly midway between Regulus and Denebola and just 2.5° south of the bright spiral galaxy M96. Its eastward motion relative to the starry backdrop carries it into Virgo the Maiden on the 25th. Mars remains on the far side of the solar system from Earth and thus appears small (5" across) and featureless through a telescope.

Comet ISON should be a fine target through binoculars and telescopes before dawn and an easy, if not spectacular, naked-eye object late in the month. The comet races from Leo, through Virgo, and into Libra as it heads toward its closest approach to the Sun on November 28. Along the way, it passes Virgo's brightest star, Spica, on the 17th and 18th. The following week, it appears near Mercury and Saturn. For complete comet observing information, see "Comet ISON blazes into glory" on p. 54.

Mercury passes between Earth and the Sun on November 1 and then quickly climbs into view before dawn. At greatest western elongation on the 17th, it stands 10° high in the east-southeast 45 minutes before sunrise. The innermost planet then shines at magnitude –0.6, so it stands out against the twilight sky.

The inner planet's relatively high altitude and brightness makes this its finest morning appearance of the year. If you can tear yourself away from Comet ISON long enough to aim your telescope at the planet, you will see a disk that is 7" in diameter and about 60 percent lit.

Mercury points the way to **Saturn** on November 25 and 26, when the inner planet lies less than 1° from the ringed world. On the 25th, Mercury appears higher than its companion. The two switch positions the following morning. If you want to observe Saturn through a telescope, wait until it climbs higher in next month's sky.

Residents along North America's East Coast can witness a partial **solar eclipse** as the Sun rises November 3. From Boston, the Moon covers 63 percent of the Sun's diameter as the pair rises. In Miami, our satellite hides 48 percent of the Sun from view. If you watch the partial eclipse, be sure to look through a safe solar filter.

By the afternoon of the 3rd, the Moon's shadow sweeps across equatorial Africa. People situated along the narrow path of totality will see the Sun's disk disappear behind the Moon and usher in one of nature's finest spectacles. For details on the total eclipse, see "Totality crosses Africa" on p. 60.

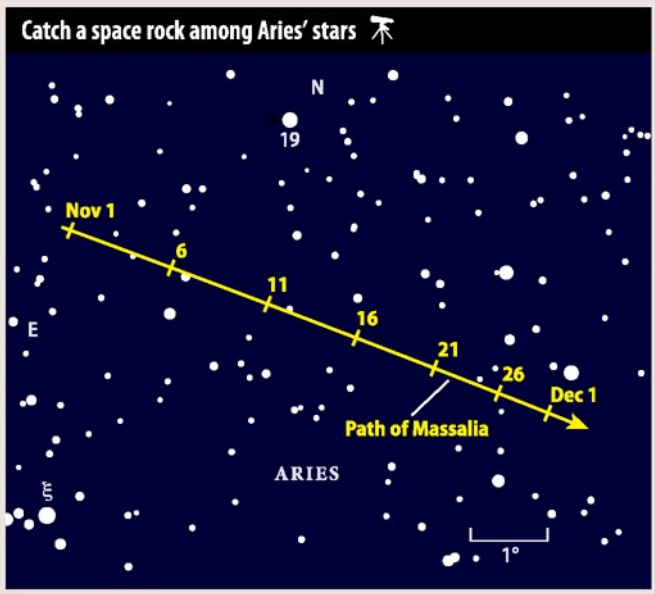
LOCATING**ASTEROIDS**

Massalia hoofs it beneath the Ram

As Aries the Ram climbs high in the southeast during mid-evening, your telescope can reveal the asteroid 20 Massalia hiding in its fleece. From the suburbs, the celestial Ram's three-star pattern looks like a golf club or hockey stick, but a bit more light pollution or haze reduces it to a wide pair. On your path to our quarry, stop for a couple of minutes to look at the Ram's fainter third star, Gamma (γ) Arietis. This classic double star looks like a distant car's headlights when viewed at magnifications of 100x or more.

Glowing at 9th magnitude, Massalia is a reasonable target for a 6-inch scope from the city or a 3-incher under a darker sky. You'll have to take some care hopping across the open pasture from Aries' brightest stars to the main-belt asteroid. Massalia lies nearly 10° south of the stars, twice the gap between the handle and tip of the stick pattern. It's a more comfortable 2° hop from the 6th-magnitude star 19 Arietis.

Use the finder chart below to triangulate your way to the right area. Then make a quick sketch of the eyepiece view showing a half-dozen stars. Note which dot you think is the asteroid, and return a night or two later to confirm that it has moved. That's basically the method Jean Chacornac and Antonin de Gasparis used when they independently discovered Massalia in September 1852.



The 9th-magnitude asteroid Massalia reached its peak in late October, but it remains a tempting target for observers this month. ASTRONOMY: KELLIE JAEGER

GET DAILY UPDATES ON YOUR NIGHT SKY AT www.Astronomy.com/skythisweek.

WorldMags.net

Anatomy of a COMET

Slip into a coma, sweep up a dust tail, and brace yourself against the solar wind.

by Sarah Scoles; illustrations by Roen Kelly

Sarah Scoles *is an associate editor of* Astronomy.

Dust tail

Ion tail

Comet tail
90 million miles
(145 million km)

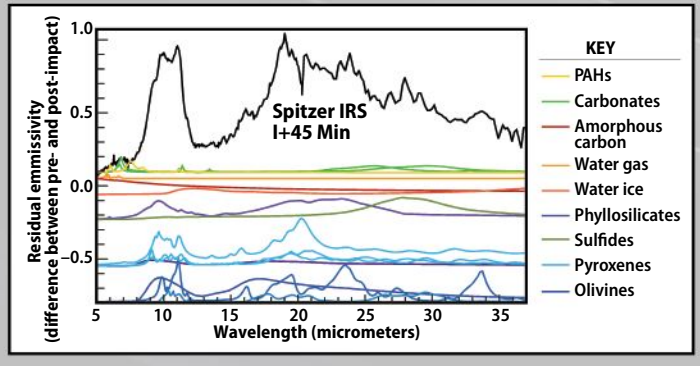
Cometopause

At the cometopause, the charged particle population changes demographics. Closer to the Sun, the plasma comes mostly from the solar wind, but here it is mostly from the coma.

The solar wind strips electrons from the neutral gases surrounding the comet's nucleus. The gas then has a positive charge and so is magnetically vulnerable — specifically to the Sun's magnetic field. The field drapes itself around the comet and extends away from the Sun — in exactly the direction we see the ion tail, where the charged particles from the comet stream backward.

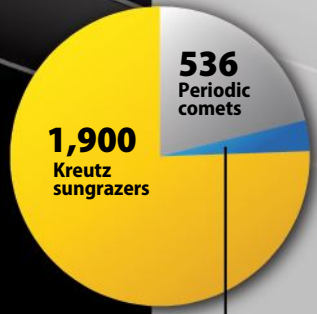
A comet's curved dust tail is its most iconic feature. It can extend for 6 million miles (10 million kilometers), tracing the comet's motion. When the comet gets as close to the Sun as Mars is, the star's radiation exerts enough pressure on the particles to force them from the coma and out into space.

Nuclear spectrum



In 2005, NASA scientists crashed the Deep Impact probe into Comet 9P/Tempel. The ejected material emitted radiation, allowing astronomers to determine its composition. This plot shows the main spectrum (black) and the components that combine to create it, including water and organic compounds. The comet was dustier than astronomers expected, and although the nucleus did appear to be solid, it was 75 percent empty space, comparable to powdery snow. NASA/UM C. M. LISSE, ET AL.

Comet distribution



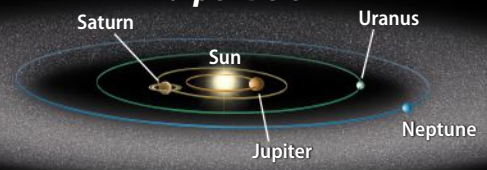
Periodic comets have appeared multiple times, while non-periodic comets have dropped by only once since humans began keeping records. Non-periodic comets have orbits that don't bring them back into view for hundreds or thousands of years. Most known comets, though, are Kreutz sungrazers, which can go within 1,000 miles (1,600 kilometers) of the Sun's surface. Scientists think they all are pieces of a comet that broke up centuries ago.

WorldMags.net

Oort Cloud

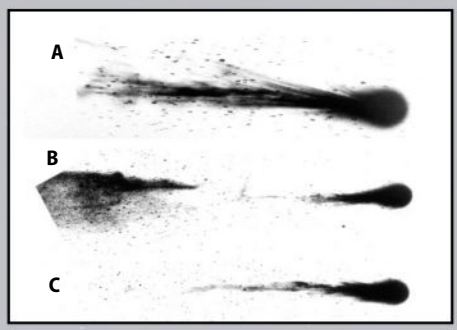
The Oort Cloud is composed of 1–2 trillion small icy bodies nearly a light-year from the Sun. Scientists have not yet detected it, though, because its constituent dirty snowballs do not emit their own light and are too distant to reflect that of our star. But these solar-system leftovers appear one at a time as long-period comets. Gravitational interactions pluck Oort Cloud objects from their distant orbits and send them hurtling into the inner solar system.

Kuiper Belt



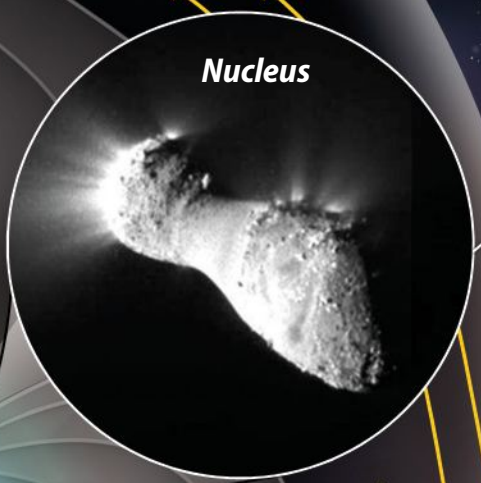
The Kuiper Belt is a group of planetesimals that extends from Neptune's orbit to 4.6 billion miles (7.4 billion kilometers) from the Sun. Some 100,000 of its objects are more than 60 miles (100km) across. The giant gas planets tug and push these objects, sending some of them — which we see as periodic comets — into the inner solar system.

Disconnection event



If the Sun is highly active when the comet is approaching, observers may witness a dramatic disconnection event, when the ion tail splits from the comet itself. When the Sun ejects a swarm of charged particles from its corona, these particles have their own magnetic field, which can bump into oppositely directed lines surrounding the comet. The two fields may link up, causing a burst of energy that can rip the tail from its parent body, as it did in the case of Comet Halley during its 1986 appearance, imaged above. PATRICK MOORE COLLECTION

Nucleus



The nucleus is the only solid part of the comet, but it reflects less sunlight than asphalt. This conglomeration of rock, dust, water ice, organic compounds, and frozen gases is only between 300 feet (90 meters) and 25 miles (100 kilometers) across. Having insufficient mass for gravity to smooth its edges, the nucleus' shape remains irregular. This is an image of Comet 103P/Hartley taken when the Deep Impact spacecraft flew by. NASA/JPL-CALTECH/UMD

Bow shock

The solar wind, because it has an electrical charge, curves around the nucleus's magnetic field. Where the wind's speed drops from supersonic to subsonic, a bow shock forms, just like it would in front of a jet. Ions from the comet concentrate along the magnetic field, "loading" it and changing its shape on the backside of the comet. The ions that follow this changed magnetic field form the comet's ion tail.

Nucleus
6 miles (10km)

Coma

600,000 miles (1,000,000km)

A thin, temporary atmosphere called the coma forms around the comet as it nears the Sun. It is made of dust and sublimated ices (mostly water, carbon dioxide, and ammonia) and gives comets their fuzzy appearance.

Hydrogen envelope

Hydrogen, most likely from water vapor, forms a gaseous shell around the coma, growing larger as the comet ventures closer to the Sun.

The Sun releases a stream of high-energy charged particles all the time. This solar wind changes some of the neutral gas surrounding the comet into charged gas — ionizing it. The solar magnetic field then sweeps the ionized compounds along its lines into space, and the net positive charge around the comet creates its magnetosphere.

Anti-tail

Occasionally, the acute observer can see a tail that seems to point opposite the ion tail. However, this phenomenon, called an anti-tail, is an illusion. When Earth passes through the comet's orbital plane, where a sheet of dust follows the comet, we see the sheet's edge, which appears as a thin line appearing to point toward the Sun.

Solar wind

Sun

Astronomy magazine

WorldMags.net







20 bright comets o

Each of these cosmic visitors of the past half-century told a unique story and captured the attentions of observers and imagers. **by Karri Ferron**

Comets are the drama queens of the solar system: They're unpredictable yet memorable, and they follow their own eccentric paths. In the past half-century, six — Ikeya-Seki (C/1965 S1), Bennett (C/1969 Y1), West (C/1975 V1), Hyakutake (C/1996 B2), Hale-Bopp (C/1995 O1), and McNaught (C/2006 P1) — have earned the designation Great Comet for their truly brilliant nature and widespread visibility, while many others missed that designation yet still reached naked-eye brightness and put on shows for amateur astronomers. Each of the 20 comets pictured has had a story to tell, generated an anecdote unique to its appearance, and created a memory for thousands — if not millions — of awed observers watching its voyage through the inner solar system.

1 COMET MCNAUGHT (C/2006 P1)
Robert McNaught was no stranger to comet discoveries when he uncovered C/2006 P1 on August 7, 2006; it was his 31st, after all. But this Comet McNaught was different. Its journey into the inner solar system took it within 0.171 astronomical unit (where 1 AU is the average Earth-Sun distance) of the Sun on January 12, 2007, and it peaked in brightness the following days at magnitude –5.5. The comet was a stunner in the Southern Hemisphere, sporting luminous bands in a tail that stretched some 35°. RICHARD SIMON

2 COMET BENNETT (C/1969 Y1)
Comet Bennett, discovered by John Caister Bennett on December 28, 1969, got the 1970s started off on the right foot. The first Great Comet since Ikeya-Seki, Bennett peaked at a formidable magnitude 0.0 just days after passing 0.538 AU from the Sun on March 20, 1970. During this time, observers and scientists paid particular attention to the coma, which showed short jets extending from the sunward side of the nucleus. LPL/UNIV. OF ARIZONA

3 COMET NEAT (C/2002 V1)
C/2002 V1, discovered November 6, 2002, in the course of NASA's Near Earth Asteroid Tracking (NEAT) program, proved difficult to predict as it reached perihelion (closest approach to the Sun) February 18, 2003. It rapidly brightened throughout January 2003, but that rate unexpectedly slowed as it neared its 0.099 AU passage of the Sun. Still, without much fanfare, Comet NEAT peaked at magnitude –0.5 in February to become the seventh-brightest comet in the past 50 years. JACK NEWTON

Karri Ferron *is an* Astronomy *assistant editor. The first Great Comet she observed was Hale-Bopp (C/1995 O1) while in grade school.*

WorldMags.net





f the past 50 years



4 COMET IKEYA-SEKI (C/1965 S1)
Comet Ikeya-Seki offered no hint of its future glory when Kaoru Ikeya and Tsutomu Seki independently discovered it September 18, 1965. Initial measurements suggested a less than exciting perihelion, but follow-up observations showed Ikeya-Seki was actually a sungrazer with an orbit similar to the Great Comet of 1882. The celestial visitor became visible to the naked eye in broad daylight October 20, peaking around magnitude –10. As it approached a perihelion distance of 0.008 AU the following day, it broke into three separate pieces. By late October, tail length estimates reached 30°. ROGER LYNDS/NOAO/AURA/NSF

5 COMET HALE-BOPP (C/1995 O1)
Alan Hale and Thomas Bopp independently discovered Comet Hale-Bopp on July 23, 1995, after one of the longest dry spells in the history of the search for these solar system interlopers. To add to the finding's distinction, the object then lay 7.1 AU from the Sun, nearly twice the normal discovery distance at the time. Comet Hale-Bopp became visible to the naked eye May 20, 1996, and remained so for 18 months — a record. It peaked at magnitude –0.8 the following March. GERALD RHEMANN

6 COMET NEAT (C/2001 Q4)
C/2001 Q4, found August 24, 2001, during NASA's Near Earth Asteroid Tracking (NEAT) program, was a little difficult for scientists to pin down initially due to its unusual, almost perpendicular retrograde orbit. In the first two weeks after its discovery, Comet NEAT's predicted perihelion time changed by more than a year. Once astronomers confirmed a May 15, 2004, date of closest passage to the Sun, though, the comet acted as expected, peaking at magnitude 2.8 in Northern Hemisphere skies. T. RECTOR (UNIV. OF ALASKA ANCHORAGE)/Z. LEVAY & L. FRATTARE (STScI)/WIYN/NOAO/AURA/NSF

WorldMags.net

7 COMET 1P/HALLEY (1986 APPARITION)
History's first and foremost periodic comet, 1P/Halley, returned to the night skies in 1982 for its most observed appearance on record. Unfortunately, celestial geometry wasn't on observers' sides: Perihelion occurred February 9, 1986, when Halley was on the opposite side of the Sun from Earth. Still, it peaked at magnitude 2.4 in early March, putting on a decent show for those in the Southern Hemisphere. ALFRED LILGE

8 COMET LINEAR (C/2000 WM1)
Members of the LIncoln Near-Earth Asteroid Research (LINEAR) project discovered their last non-periodic comet of 2000 (their eighth of the year) in images obtained December 16. The celestial visitor spent most of 2001 gradually brightening, but it began increasing its magnitude faster than expected in late November. After passing 0.55 AU from the Sun on January 22, 2002, Comet LINEAR experienced an outburst, ultimately peaking at magnitude 2.5 before it resumed fading. MICHAEL JÄGER

9 COMET IKEYA-ZHANG (C/2002 C1)
Comet Ikeya-Zhang actually has two official designations. Upon the initial announcement, it became C/2002 C1, the first non-periodic comet discovered in February 2002. Shortly thereafter, though, orbital studies revealed that Ikeya-Zhang likely was the same comet Polish astronomer Johannes Hevelius had observed in 1661, making it a periodic comet (153P/Ikeya-Zhang) with the longest-known orbital period. For its second recorded apparition, Ikeya-Zhang peaked at magnitude 2.9 around its March 18, 2002, perihelion passage. JACK NEWTON

10 COMET MACHHOLZ (C/2004 Q2)
It had been nearly 10 years since visual observer Don Machholz had discovered his last comet when he came upon a faint fuzzball August 27, 2004. Although orbital calculations indicated a relatively distant perihelion (1.205 AU) January 24, 2005, this Comet Machholz exceeded predictions as it peaked at an unusually bright magnitude 3.5 at the end of 2004. ADAM BLOCK/NOAO/AURA/NSF

11 COMET BRADFIELD (C/2004 F4)
William A. Bradfield discovered his 18th comet March 23, 2004 — a solar system interloper that would become the brightest of his finds. Comet Bradfield joined two other early 2004 naked-eye comets — NEAT (C/2001 Q4) and LINEAR (C/2002 T7) — in the sky as it peaked at magnitude 3.3 shortly after passing only 0.169 AU from the Sun on April 17. GERALD RHEMANN AND MICHAEL JÄGER

12 COMET KOHOUTEK (C/1973 E1)
Some may wonder why Comet Kohoutek appears in this gallery. After all, people often think of it as one of the biggest comet "flops" of modern times. Yes, Kohoutek never shone brighter than Venus as scientists initially predicted after its March 7, 1973, discovery. It did still reach naked-eye visibility, however, peaking at magnitude 0.0 around perihelion December 28, 1973, which makes it the 10th-brightest comet of the past 50 years. STEVE REED

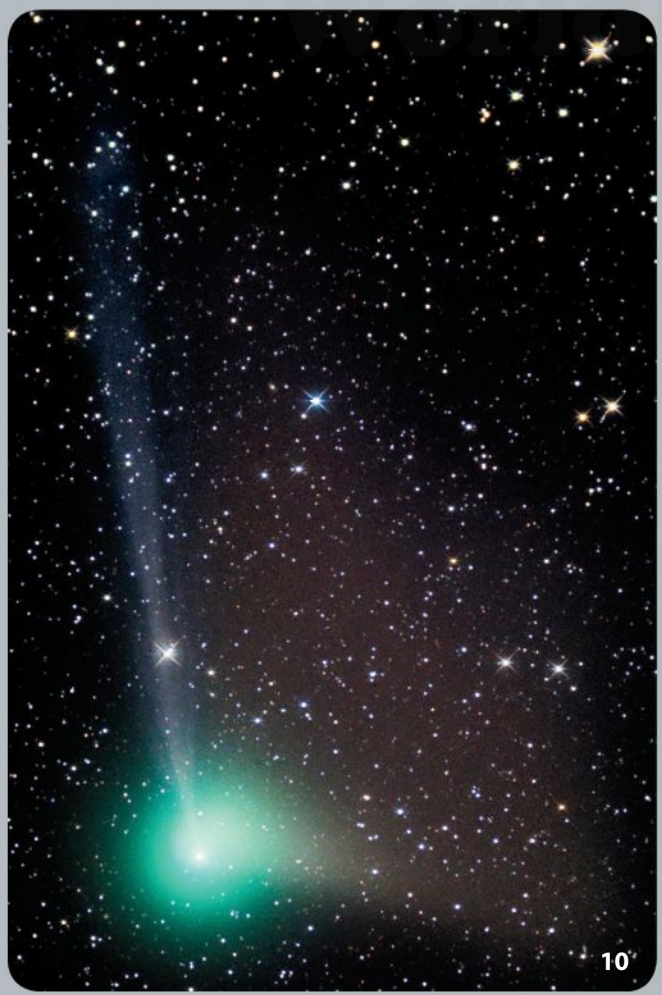
13 COMET LOVEJOY (C/2011 W3)
Amateur astronomer Terry Lovejoy's comet discovery of November 27, 2011, C/2011 W3, took the Internet by storm that year as its projected orbit indicated the celestial visitor was in fact a sungrazer and would pass only 0.0056 AU from the Sun at perihelion December 15. Many experts expected the small comet to break up during its close passage, with bets being on when rather than if. Defying all odds, Comet Lovejoy survived its plunge into the Sun's corona, with observations as it returned to the night sky indicating a peak magnitude of about –2.9. WAYNE ENGLAND


7


8


9

WorldMags.net



10



11



12



13

WorldMags.net

14 COMET HYAKUTAKE (C/1996 B2)
Japanese amateur astronomer Yuji Hyakutake was surprised when he discovered C/1996 B2 through binoculars January 30, 1996, in the same region of sky he had found a different dirty snowball five weeks earlier. The comet came upon observers quickly, as it reached naked-eye visibility February 26 and peaked at magnitude 0.0 in late March. Comet Hyakutake sported a spectacular tail, which reached an estimated 90°. MICHAEL STECKER

15 COMET 17P/HOLMES (2007 APPARITION)
Comet 17P/Holmes, discovered in 1892, surprised observers in 2007 with a brilliant outburst months after its May 4 perihelion. In just 42 hours between October 23 and 24, the comet brightened dramatically, from magnitude 17 to magnitude 2.8, and peaked at magnitude 2.4 by the end of the month. During that time, Comet Holmes' coma expanded to an apparent diameter of nearly 1°. NASA/ESA/ALAN DYER

16 COMET PANSTARRS (C/2011 L4)
C/2011 L4, one of many comets discovered by the Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) 1 telescope in Hawaii, is the comet to beat in 2013. With a peak magnitude of –1 shortly after its March 10, 2013, perihelion, Comet PANSTARRS was a stunning binocular — and later telescope — target. But with Comet ISON (C/2012 S1) expected to outperform many of the other dirty snowballs in this gallery, Comet PANSTARRS will likely rank as the second brightest in this "Year of the Comet." GERALD RHEMANN

17 COMET IRAS-ARAKI-ALCOCK (C/1983 H1)
Although C/1983 H1 didn't earn the label Great Comet due to its size and inactivity, it was a memorable visitor. In May 1983, it passed within 2.7 million miles (4.6 million kilometers [0.029 AU]) of Earth, the second-closest flyby of a comet in the 20th century. As it peaked at magnitude 1.7, Comet IRAS-Araki-Alcock swept across some 30° of the sky per day. H. NEBEL

18 COMET LINEAR (C/2002 T7)
Scientists with the LIncoln Near-Earth Asteroid Research (LINEAR) project first reported the discovery of an asteroidal object October 14, 2002; C/2002 T7 didn't earn its comet designation until October 29 in an International Astronomical Union circular. This Comet LINEAR slowly brightened throughout 2003 before peaking at magnitude 2.7 in late May 2004. This brightness wasn't consistent, though; C/2002 T7 surprised many observers with fluctuations in magnitude throughout that month. PAT BALFOUR AND CURT HARRIS/ADAM BLOCK/NOAO/AURA/NSF

19 COMET WEST (C/1975 V1)
Comet West first showed up on photographic plates from the 100-centimeter Schmidt camera at the European Southern Observatory in La Silla, Chile, as early as August 10, 1975. Some astronomers had low expectations for the celestial visitor even as it approached its February 25, 1976, perihelion, saying it probably wouldn't be an impressive sight when it emerged from behind the Sun. Comet West surprised everyone, however, when it became visible in broad daylight just after passing 0.197 AU from our star. West peaked at magnitude –3 in early March. P. STÄTTMAYER/ESO

20 COMET AARSETH-BREWINGTON (C/1989 W1)
The 1980s ended on a high note thanks to Comet Aarseth-Brewington, discovered independently November 16, 1989, by Knut Aarseth and Howard Brewington. Observers described the dirty snowball as a "miniature Comet West" during its peak in late December at magnitude 2.8. MICHAEL STECKER


14


15


16

WorldMags.net



17



19



18



20

CHECK OUT MORE AMAZING IMAGES OF BRIGHT COMETS AT **www.Astronomy.com/toc.**

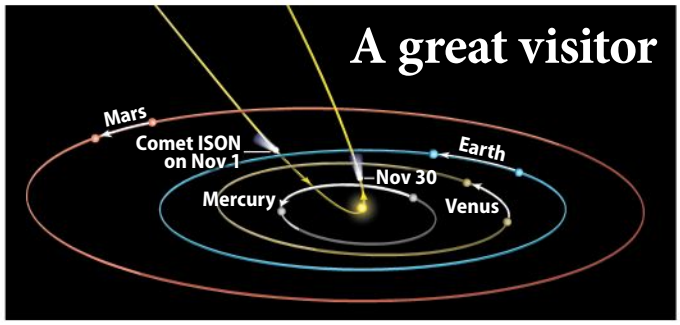
WorldMags.net

WorldMags.net

PREDICTING A PATH

Q: HOW DO SCIENTISTS PREDICT THE ORBIT AND APPARENT "PEAK" MAGNITUDE OF AN INCOMING COMET SUCH AS COMET ISON (C/2012 S1) WHEN IT IS FAR FROM EARTH?

Matthew Schewe, *Eden Prairie, Minnesota*



Using the laws of physics, scientists determined six orbital elements of the path of Comet ISON (C/2012 S1) from just a few observations. They know the comet will reach its closest distance to the Sun on November 28 and how far it will be at that point, but it's uncertain how bright it will appear. *ASTRONOMY:* ROEN KELLY

A: Comets are like small planets that follow orbits of all shapes and sizes around the Sun. Usually, these orbits are chaotic and highly elongated — taking the comets far from our star at their farthest points — and they can change significantly due to the gravitational influences of the major planets. To determine a comet's orbit, we start by observing its positions with respect to the cataloged locations of background stars, and then apply the laws of physics.

We calculate six orbital "elements" from at least three observations spread out over days: the time and distance of the comet's closest approach to the Sun (called perihelion), the eccentricity of the orbit (how stretched out it is), and three angles specifying the orbital plane of the comet with respect to Earth's orbit. (The longer we see a comet, the better we can determine these elements.) Some comets pass extremely close to our star, while others have much farther-out perihelion distances.

We can predict how bright a comet will become with only some degree of certainty because it contains "volatile" ices that turn directly to gas as it approaches the Sun. Comets' nuclei have varying amounts of ice and dust. How much of this material comes off during passages through the inner solar system varies tremendously among these objects and affects their brightnesses. A comet that passes closer to the Sun will lose more material and form a visible atmosphere (called a coma) and/or tail; more material increases the brightness.

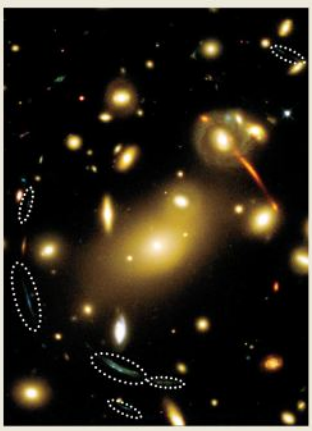
Most comets follow our general predictions fairly well, but not all do. Sometimes the fragile cometary nucleus can break apart or display outbursts of material; many comets that go close to the Sun fragment, and some disappear altogether.

Thus, for Comet ISON (C/2012 S1), which has a long orbital period, we conservatively expect that the comet's visual magnitude will brighten in relation to the comet's distance from the Sun. When observers discovered this comet last year, it was near 6 astronomical units (an AU is basically the average Earth-Sun distance) from our star and Earth; by April 2013, it was still 4 AU away. Brightness measurements have been consistent thus far with our predictions, which suggests that it may brighten to magnitude –6 on November 28, 2013, when it will be only 0.012 AU from the Sun at perihelion. Comet ISON, however, will be only about 1° from the Sun as seen from Earth and thus exceedingly difficult (and dangerous) to view.

Two days before or after perihelion, when the comet is about 8° from the Sun, we expect its brightness to be closer to magnitude 0.5 (but still hard to see in bright twilight — when it's just above a clear horizon and the Sun is just below the horizon). A couple days further removed from perihelion, the comet is likely to be around magnitude 2 and still only 13° to 15° from the Sun.

Comet ISON has an absolute magnitude of around 7, which is not particularly bright. For comparison, Comet Hale-Bopp (C/1995 O1) had an absolute magnitude of around –1.0.

Using recent observations with the Hubble Space Telescope, a team of astronomers deduced that the nucleus of Comet ISON is only around 1.2 miles (2 kilometers) in size or less. This suggests that the comet may not survive its passage so close to the Sun, and several scenarios could take place: It could produce a nice long tail that would be a



The extreme mass within galaxy cluster Abell 2218 bends the light of a more distant galaxy. NASA/ESA/ A. FRUCHTER AND THE ERO TEAM (STScI/ST-ECF)

Q: IN SOME PHOTOGRAPHS OF GALAXY CLUSTERS, WHY ARE THE ARCS OF A LENSED GALAXY BLUE?

Stephen Peterson, *Hurricane, Utah*

A: Galaxy clusters contain hundreds of galaxies, a lot of hot gas, and even more invisible dark matter. A cluster's extreme mass warps space-time, and light from more distant objects follows those bends and lands on scientists' detectors.

The background galaxies are from an earlier time in the universe than the foreground galaxy cluster, and thus astronomers see them at younger stages. Young galaxies hold a lot of forming stars, which glow in blue and ultraviolet light due to the high energy that is radiated during star birth. That's why the warped images of a distant galaxy — i.e., the arcs you mention — lensed by a foreground galaxy cluster appear blue.

Liz Kruesi, *Associate Editor*

WorldMags.net

WorldMags.net

splendid sight in the days before and after perihelion; it might break into large pieces that survive past perihelion, opening up more volatile ices in the inner original nucleus and thus surging in brightness; it could break apart with no nuclear pieces (or coma) visible after perihelion; or the comet might survive intact.

The Cometary Science Archive at Harvard University maintains a Web page for this comet at http://tinyurl.com/CSL2012S1, where scientists display detailed information, updates, observations, and photographs. You can also follow *Astronomy*'s comet coverage at www.Astronomy.com/ISON.

Daniel W. E. Green
Harvard University, Cambridge, Massachusetts

Q: IS VENUS ALWAYS EITHER A "MORNING STAR" OR AN "EVENING STAR" DURING CERTAIN TIMES OF THE YEAR?

Ray Montello
League City, Texas

A: Unfortunately, Venus' path through the sky is a bit more complicated than that. This autumn, Earth's neighbor shines brilliantly in the west after sunset. It reaches its greatest elongation from the Sun — its greatest angular distance from the Sun on the sky — on November 1, when it lies 47° east of our star. The planet grows brighter as it falls back toward the Sun in our sky, reaching its peak in early December. This "evening star" then shines at magnitude –4.9 — some 25 times brighter than the night sky's brightest star, Sirius.

Venus will pass between the Sun and Earth in January and then quickly rise into view before dawn. It will remain the "morning star" until next September. After passing on the far side of the Sun, it will return to view after sunset as an "evening star" in December 2014 and stay there until the following summer. The pattern repeats itself every 583.92 days (approximately 19 months). This is Venus' "synodic period," or the time it takes for the planet to return to the same alignment relative to Earth. Compare this with its 224.7-day shorter "sidereal period," the time it takes to return to the same position relative to the background stars.

Although Venus doesn't appear in the same spot in the sky year after year, it does show a more subtle pattern. If you multiply its synodic period by 5, you come up with 2,919.6 days. What does this ungainly number have to do with anything? If you divide it by 365.26 days (the time it takes Earth to revolve around the Sun), you get 7.993 — just about 8. So nearly every eight years, Venus returns to the same area of sky at the same time of year. Its fifth greatest eastern elongation after the one November 1 will occur October 29, 2021.

Richard Talcott
Senior Editor



The theory of special relativity shows itself in everyday life. A person who shines a flashlight while traveling in a railway car still measures that light moving at the speed of light, just as an onlooker would. *ASTRONOMY:* ROEN KELLY

Q: IN THE LARGE HADRON COLLIDER, TWO STREAMS OF PROTONS TRAVEL IN OPPOSITE DIRECTIONS AT NEAR LIGHT-SPEED BEFORE THEY COLLIDE WITH EACH OTHER. DOES THIS MEAN THAT THE TWO PARTICLE STREAMS ARE MOVING AT NEARLY TWICE THE SPEED OF LIGHT RELATIVE TO EACH OTHER?

Robert Keeler
Culver City, California

A: This question gets to the heart of the special theory of relativity. Let's take a simpler example to start with. Imagine someone standing on a moving railroad car and shining a flashlight. What is the velocity of that beam as seen by someone on the ground? According to the laws of physics instilled by Isaac Newton and Galileo Galilei, the person on the ground would just add the velocities of the car and the beam, and would see the beam moving faster than the speed of light.

But we don't live in that world, as Albert Einstein showed in 1905. In our relativistic world, moving clocks slow down and moving objects shrink in the direction of motion. Because the definition of velocity is the change in distance divided by the change in time, it should come as no surprise that the addition of velocities is more complicated for Einsteinian physics than it was for Newtonian physics. In the above example, the light's distance has shortened and its clock has slowed. Thus, both the person on the railroad car and the onlooker see the beam moving at 186,282 miles per second (299,792 kilometers/second) — the speed of light.

The same thing happens with the protons in the Large Hadron Collider. If you could somehow sit on one proton and measure the speed of the approaching one, you would see it moving toward you at nearly the speed of light (technically, 0.999999991 percent of light-speed).

These relativistic kinds of effects become important only for objects moving at nearly the speed of light. For ordinary speeds, Newton's and Galileo's rules work just fine.

James Trefil
George Mason University, Fairfax, Virginia

Send us your questions

Send your astronomy questions via email to **askastro@astronomy.com**, or write to Ask Astro, P. O. Box 1612, Waukesha, WI 53187. Be sure to tell us your full name and where you live. Unfortunately, we cannot answer all questions submitted.

WorldMags.net

WorldMags.net

Comet ISON blazes into GLORY

This frozen ball of gas and dust puts on a show in the predawn sky before reaching peak brightness in late November as it skims above the Sun's surface. **by Richard Talcott**



Comet ISON glowed around 16th magnitude and had developed a short tail when the Hubble Space Telescope captured it May 8. NASA/ESA/THE HUBBLE HERITAGE TEAM (STScI/AURA)

Let's lay our cards on the table at the outset: No one really knows how bright Comet ISON (C/2012 S1) will get. Lots of people think they know how this comet will perform as it plunges toward the Sun this month. Optimists tout numbers that have many amateur astronomers giddy with excitement. If they're right, the comet could rival the Full Moon when it passes closest to the Sun at perihelion November 28 and remain as bright as the planet Jupiter for several days around then.

Pessimists peddle figures that would bring tears to the cheerleading squad of an undefeated football team during Homecoming. If they prove prophetic, ISON may not even reach naked-eye visibility and will go down in the annals of astronomical history with Comet Kohoutek (C/1973 E1), which failed to live up to its billing as the "Comet of the Century" 40 years ago.

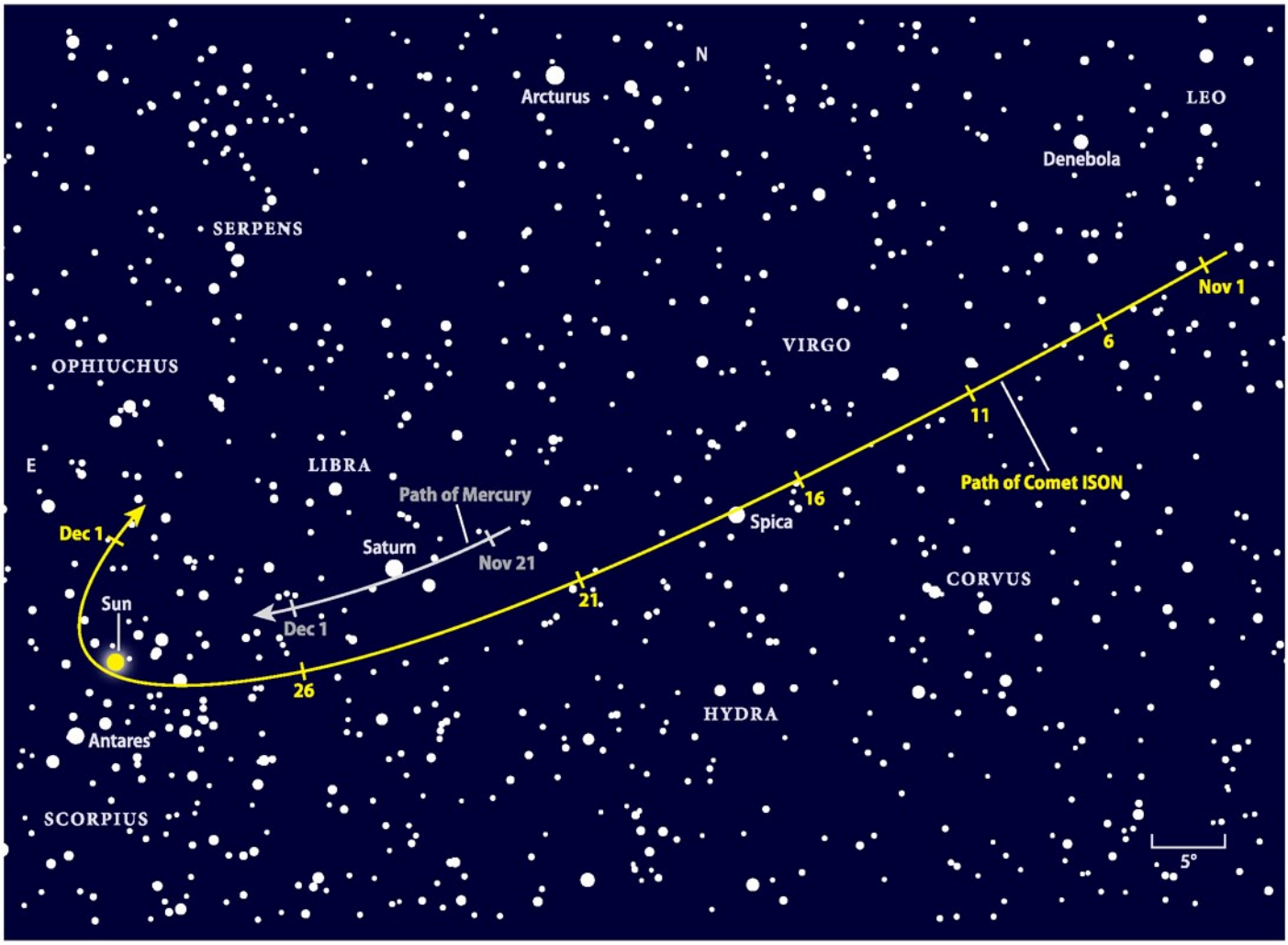
Here's what we do know. This first-time visitor to the inner solar system appeared abnormally bright when astronomers Vitali Nevski and Artyom Novichonok of the International Scientific Optical Network — ISON for short — discovered it September 21, 2012. Despite residing beyond the orbit of Jupiter, it shone at 19th magnitude, an intensity almost unheard of for such a distant comet.

Astronomers realized that the object's nucleus must be covered with ices that were sublimating (turning directly into gas) fiercely under the gentle heat of the faraway Sun. Scientists quickly calculated the object's orbit and realized that it would dive close to our star in November 2013. If the comet's rate of outgassing rose as expected

Richard Talcott *is an* Astronomy *senior editor and author of* Teach Yourself Visually Astronomy *(Wiley Publishing, 2008).*

WorldMags.net

WorldMags.net



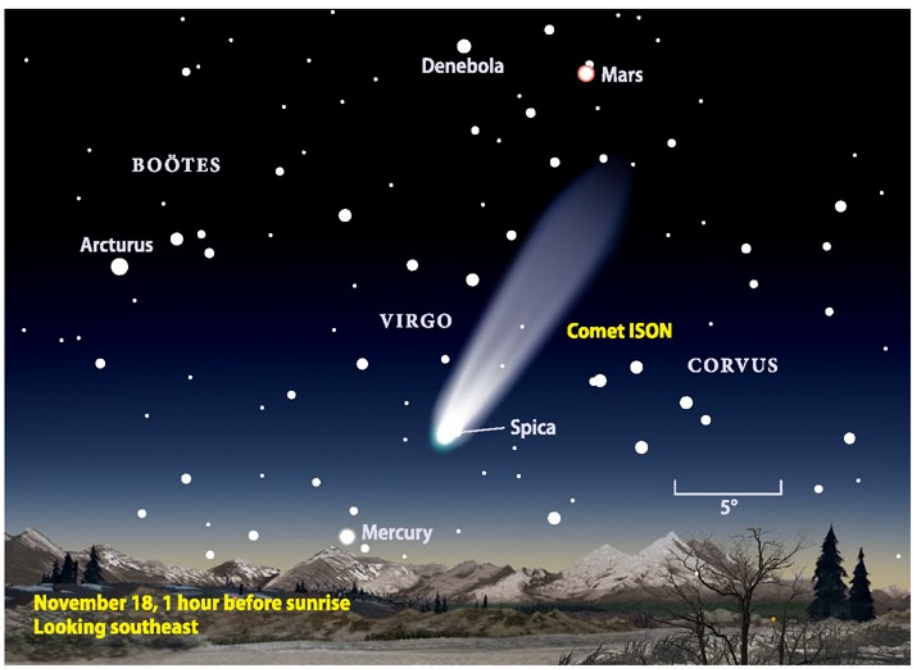
Comet ISON sweeps across the morning sky in November. The map shows all stars down to magnitude 6.5. *ASTRONOMY*: KELLIE JAEGER

as it neared the Sun, then viewers would be in for an extraordinary show.

Unfortunately, the comet hasn't brightened as quickly as those early estimates led us to believe. ISON appeared about two magnitudes (approximately six times) fainter than expected when it disappeared into the Sun's glare in May. Of course, if the comet ends up being just two magnitudes fainter than the Full Moon at perihelion, that's still pretty impressive.

But some researchers think that the dimming is a sign that volatile ices, such as carbon monoxide and carbon dioxide that sublimate at low temperatures, were in play back in September 2012. Once water ice takes over as the comet's main energy source, their thinking goes, ISON will fall further behind the brightening curve.

The answer to this year's hottest question in amateur astronomy — How bright will ISON get? — won't be answered until more



Comet ISON streaks across Virgo in mid-November. It passes close to the 1st-magnitude star Spica on the 17th and 18th. *ASTRONOMY*: KELLIE JAEGER

WorldMags.net

CATCH AUTUMN'S SECOND-BEST COMET

Most eyes will be on Comet ISON this month — and rightfully so. It has the potential to be a Great Comet that rivals the brightest seen for several decades. But there's another comet on display these November mornings that could match ISON's brightness during November's first half.

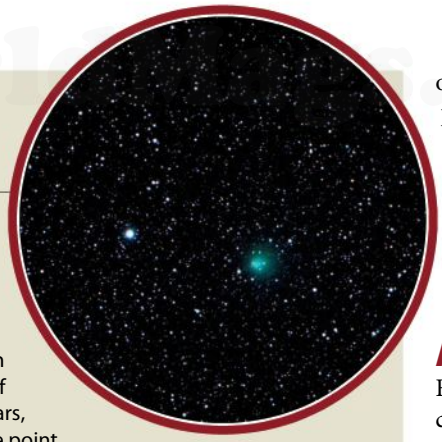
This month's "other" comet is 2P/Encke. German astronomer Johann Encke analyzed the motions of several comets observed in the late 18th and early 19th centuries and found that a single orbit could explain them all. He predicted the comet would return in 1822, and when it did, astronomers named it for him. It was the second known periodic comet, coming more than a century after its famous sibling, 1P/Halley.

Scientists quickly recognized, however, that 2P/Encke wasn't behaving right. Back in the 17th century, English physicist Isaac Newton showed how objects should move under the influence of gravity. But Encke's comet, which completes a circuit of the Sun every 3.3 years, returned to the same point in its orbit approximately three hours earlier than expected every time. Other comets showed the opposite effect, with slower motions.

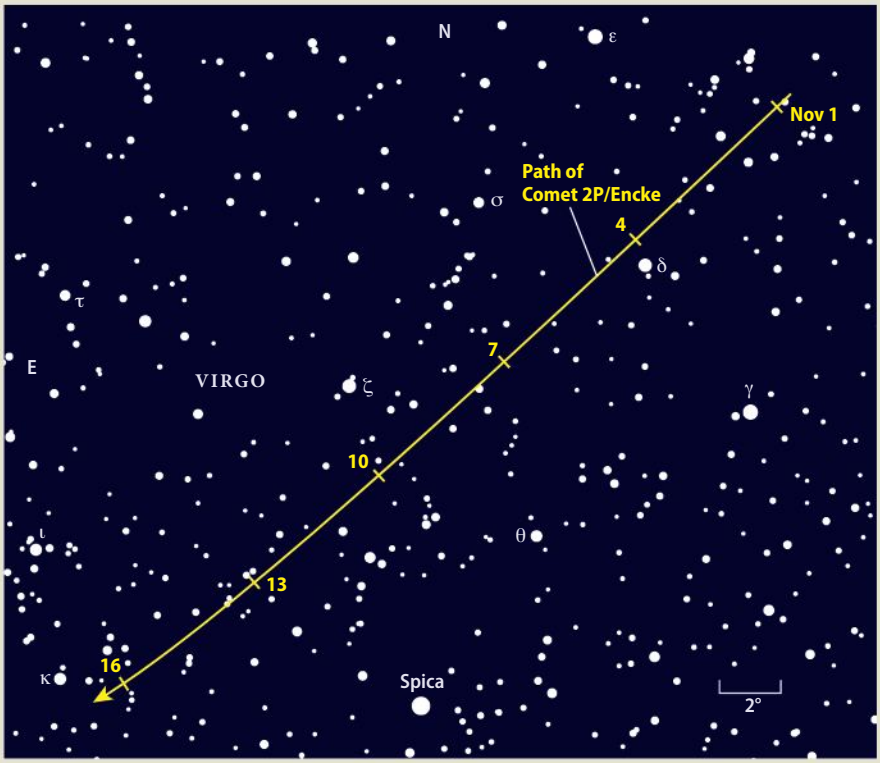
Eventually, astronomers figured out how comets work. Jets of gas and dust erupt from the nucleus as solar radiation sublimates the ices there. These jets can act like low-powered rocket thrusters and alter a comet's motion. In Encke's case, the jets noticeably speed up the object's revolution.

The 2013 return of 2P/Encke is its best morning apparition in a decade. Like ISON, it lies in the eastern sky before dawn. Encke traverses Virgo during the first half of November, passing within 7° of 1st-magnitude Spica from the 11th through the 13th. The finder chart below will help you find it throughout the month's first half. Unfortunately, Encke sinks into twilight after that and becomes much harder to see.

The comet behaves predictably at most of its returns, and astronomers estimate that it will brighten from 7th to 5th magnitude from early to mid-November, matching ISON's brightening. To see Encke best, view it through binoculars or a telescope from under a dark sky. — *R. T.*



Comet 2P/Encke appeared before dawn in November 2003. It should put on a similar show this month. MIKE HALLOWAY



Comet 2P/Encke treks across Virgo the Maiden during the first half of November, when it should brighten from 7th to 5th magnitude. *ASTRONOMY:* KELLIE JAEGER

observations arrive. As this issue went to press in August, no one had yet spotted the comet visually in the bright morning twilight. Once that occurs, probably by early September, the object's future behavior will become clearer. Just remember that when it comes to comets, surprises can crop up at any time.

Aiming for the Red Planet

For this article, we use brightness estimates calculated by the Minor Planet Center of the International Astronomical Union (IAU). They show ISON at 7th or 8th magnitude in early November. That's bright enough to see through binoculars or a small telescope from under a dark sky, and with a New Moon on November 3, the morning hours will be dark if you're away from the city during the month's first half.

On the 1st, ISON rises more than four hours before the Sun and stands 30° above the eastern horizon at the start of morning twilight. It lies in southern Leo the Lion, 12° southwest of 2nd-magnitude Denebola. But the comet will be easier to track down by scanning some 7° south-southeast of magnitude 1.5 Mars. A slim crescent Moon rises more than two hours after ISON.

If you have exceptionally clear skies this morning, you might be able to trace the comet's tail to Mars. In fact, the comet likely will sport two tails. Here's how they form. As sunlight warms the comet's nucleus — a "dirty snowball" of ice and rock only a few miles or kilometers across — the ices sublimate, gas molecules erupt from the surface, and bits of rock and dust get carried away with them.

The Sun's ultraviolet radiation ionizes the molecules by stripping electrons from them. The magnetic fields in the solar wind then drag these ions away from the Sun, creating a straight tail that emits light with a bluish cast. Solar radiation also produces a slight pressure that pushes the dust particles into a gently curving tail that follows the comet's orbit. The dust simply reflects sunlight, so it has a slightly yellowish color. Because we view ISON's orbit nearly broadside during November, the dust tail should appear fan-shaped.

With each passing day, the comet shines a little brighter, rises a few minutes later, and slips slightly lower as twilight starts to paint the sky. During November's first week, ISON should brighten by a full magnitude, appearing 2.5 times brighter than on the month's first morning.

The comet also picks up speed during November as it falls toward the Sun and

WorldMags.net

our star's gravity applies a greater force. You can see this velocity increase in ISON's motion relative to the background stars. It shifts about 1° per day at the start of the month, 2° per day to begin the second week, and 3° per day by mid-November. It will zip along at 5° per day by the time it reaches perihelion.

ISON's quickening pace means that no single constellation can hold it for long. After spending all of October and the first few days of November in Leo, it reaches that constellation's border with Virgo the Maiden on November 5. The comet remains within the Maiden's grasp until the 22nd largely because this is the sky's second-largest constellation.

A date with Spica

ISON passes near a string of 3rd- and 4th-magnitude stars along Virgo's southern flank during November's second week. But if you chart its progress, you can tell it has its sights set on the Maiden's luminary, 1st-magnitude Spica. It reaches this blue-white star's vicinity around midmonth, by which point ISON should have improved to 5th magnitude. This would bring it within range of naked eyes under a country sky and a nice binocular object from the suburbs.

On the 15th, the comet hangs 8° west-northwest of Spica. That drops to 5° the next day and to just 2° the day after that. If ISON's tail (or tails) glows brightly then, it could look like the Sword of Damocles poised above Spica. By the 18th, the comet's head appears below the bright star with the tails lying in front of it.

If you're looking to photograph Comet ISON, any of these mornings should work wonderfully. You can get superb results with a digital single-lens reflex camera, a



Comet McNaught (C/2006 P1) glowed brightly enough at its peak to see with naked eyes during daylight. Under the right conditions, ISON could match this feat. ROB RATKOWSKI

Comet McNaught (C/2006 P1) sets over the lights of Auckland, New Zealand, on January 18, 2007. Neither artificial lights nor patchy clouds overwhelmed McNaught's brilliance. The same should be true for ISON. JAMIE NEWMAN

WorldMags.net



Comet Hale-Bopp (C/1995 O1) became the gold standard for Great Comets visible from the Northern Hemisphere when it peaked in spring 1997. The comet's bluish ion tail and yellowish dust tail appeared distinct throughout its apparition. GERALD RHEMANN

WorldMags.net

MOON PHASES IN NOVEMBER

New Moon	Nov. 3
First Quarter	Nov. 9/10
Full Moon	Nov. 17
Last Quarter	Nov. 25

standard lens, and a sturdy tripod. Using manual ("M") mode, set the lens aperture as wide as possible (the lowest f/ratio) and the ISO to 400. If you keep your exposures to 15 seconds or less, you'll keep stars from trailing across your image. Experiment with different settings to see what works best under the conditions. Also try to find intriguing foreground scenes to add interest to your photos. Finally, don't be afraid to shoot in twilight — the colors add a lot of visual appeal.

Alas, the Moon returns to the sky around midmonth. It first intrudes on the predawn sky November 16, a day before Full phase. It won't leave until after perihelion. That might not be a huge problem, however, because the brightest Moons appear in the western sky while ISON remains in the east.

A planet parade

The comet should continue to brighten rapidly as perihelion approaches. Predictions show it at 4th magnitude November 22, when it should appear striking in the eastern sky an hour before sunrise. This day marks the comet's passage into Libra the Scales. It also represents the last day on which ISON rises before twilight begins for observers at 35° north latitude. Fortunately, the comet should be bright enough to see in deeper twilight, particularly if you use binoculars. And if the tails appear long and bright, they will angle up into a dark sky.

In addition to ISON, the twilight sky now also holds two bright planets. Mercury shines at magnitude –0.7 and stands 5° to the comet's left. (Unless ISON exceeds even the rosiest expectations, the innermost planet will be easier to spot.) Saturn, at magnitude 0.6, appears 4° to Mercury's lower left. By the next morning, all three solar system objects lie within 6° of one another and should show up in the field of view of 7x50 binoculars an hour before sunrise.

On November 25 and 26, Mercury lies within 1° of Saturn. The inner planet appears slightly above the ringed world on the 25th; they switch positions the following day. The comet lies one binocular field

below the planetary pair and will be difficult to see in the solar glare, even under nearly perfect conditions.

Rounding the Sun

At perihelion November 28 (Thanksgiving Day in the United States), ISON sweeps within 1.16 million miles (1.86 million km) of our star's center, or just 730,000 miles (1.16 million km) from its surface. The comet's temperature should soar to 3600° Fahrenheit (2000° Celsius), providing lots of heat to sublimate ices. If the IAU predictions pan out, ISON will peak at magnitude –4.5, equivalent to Venus' brightness. Although the comet then lies within 1° of the Sun, it might show up to amateur astronomers who carefully shield the Sun with a hand or a building.

But the best views of perihelion likely will come from a trio of solar telescopes located outside Earth's atmosphere. The Solar Terrestrial Relations Observatory (STEREO), the Solar Dynamics Observatory (SDO), and the Solar and Heliospheric Observatory (SOHO) each supply different perspectives. With its wide field of view, STEREO can follow ISON for more than a month. And with its superb resolution, SDO might be able to directly image the comet as it passes close to the Sun.

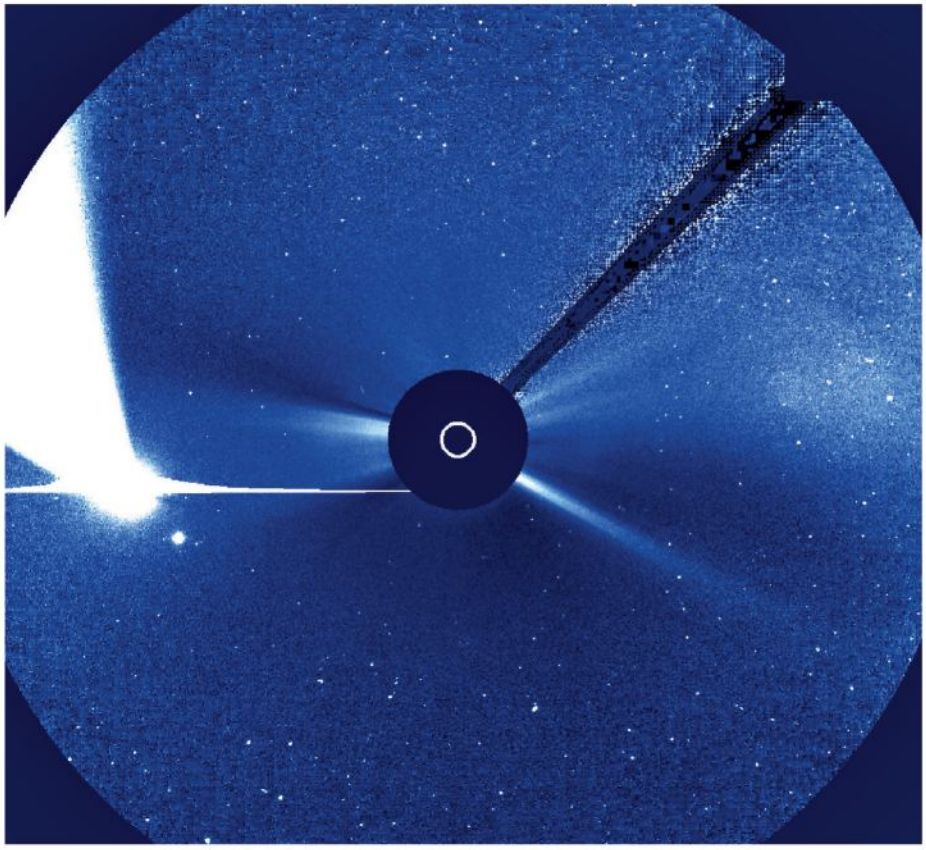
But perhaps the most intriguing images will come from SOHO. On the evening of the 26th in North America, ISON enters the field of view of SOHO's LASCO C3, a wide-field coronagraph that blocks the Sun's disk and allows views of the solar corona and any other bright nearby objects of interest (such as comets). ISON remains in the C3 field for nearly four days. On the morning of November 28, the comet arrives in the narrower field of the LASCO C2 coronagraph and stays there for approximately 10 hours.

You can access current C2 and C3 images at sohowww.nascom.nasa.gov/data/realtime-images.html. Those from the C3 coronagraph are colored blue while ones from C2 are orange.

No one knows whether ISON will survive its rendezvous with the Sun or break into multiple pieces. Most astronomers think that it will stay intact and emerge on the other side glowing brightly before dawn. If so, it will swing northward through Scorpius, Ophiuchus, Serpens, Hercules, Corona Borealis, and Draco during December. We'll be back next month with details on ISON's ongoing performance.



Comet McNaught (C/2006 P1) appeared best for northern observers in the second week of January 2007. ISON could deliver a similar show. This view shows McNaught over Greenland. LARS AND CASPER CHRISTIANSEN



Comet McNaught (C/2006 P1) passed through the Solar and Heliospheric Observatory's LASCO C3 field of view January 14, 2007. Expect a similar look when ISON reaches perihelion November 28. SOHO (ESA/NASA)

FOR CONTINUING UPDATES ON ISON'S PROGRESS, VISIT **www.Astronomy.com/ISON.**

WorldMags.net

Totality crosses Africa

Exotic locations, safaris, and an eclipse's shadow across the Dark Continent will lure travelers to this event November 3.

by JOEL K. HARRIS

"Chasing total eclipses of the Sun is probably one of the most benign forms of gambling," according to Edwin C. Krupp, director of the Griffith Observatory in Los Angeles. In my 40 years of chasing eclipses all around the world — in pursuit of the precious few minutes when I have been fortunate enough to bask in the shadow of our Moon — I have learned the validity of Krupp's observation, insofar as the likelihood of observing any one solar eclipse is concerned.

Last November's total eclipse crossed the far-northern portion of Australia's tropical region. As such events go, it was relatively easy to access. Seeing the solar eclipse this November 3, however, will require both an abundance of luck and substantial planning.

Watching from sea

This lineup of the Sun, the Moon, and Earth is a relatively rare "hybrid eclipse." The event starts off as an annular eclipse because the Earth-Moon distance isn't small enough to move Earth into the Moon's umbra (the darker inner shadow). After only 15 seconds of the Moon's shadow contacting Earth, however, our planet's curvature moves the ground contact point deeper into the lunar shadow cone, which creates a total eclipse for the remainder of the west-to-east eclipse track.

It cuts a long path just north of Earth's equator, starting at sunrise in the western Atlantic Ocean approximately 150 miles (240 kilometers) south of Bermuda. The shadow then traverses the open waters of



The central path of the November 3 eclipse begins in the Atlantic Ocean about 600 miles (373 kilometers) east of Jacksonville, Florida. Maximum eclipse occurs some 200 miles (124km) southwest of Liberia, where totality lasts 1 minute and 39 seconds. The Moon's shadow later makes landfall, with viewers seeing ever-decreasing lengths of totality. *ASTRONOMY*: ROEN KELLY

All total solar eclipses are spectacular. Few, however, occur in a setting as exotic as that of Easter Island. This image, taken July 11, 2010, shows the eclipsed Sun standing above a group of Moai — the iconic stone figures. GREG REINKING

WorldMags.net

the Atlantic Ocean. Finally, it crosses Africa's midriff, ending at sunset in the war-torn nation of Somalia.

Much of the eclipse track lies near the equator, and this gives an advantage to would-be observers. Earth rotates fastest at the equator (1,036 mph [1,667 km/h]), and its rate there will slow the relative velocity of the lunar shadow. This benefit, however, comes at a price because our planet's Intertropical Convergence Zone (ITCZ) lies almost directly on top of much of the ground track of this eclipse.

The ITCZ is a region of weather known to sailors as the doldrums. In this area, the northeast and southeast trade winds meet. On a daily basis, the water and land absorb heat from the nearly overhead Sun. That, coupled with the collision of the winds, results in thick cumulonimbus clouds, significant vertical lifting of the atmosphere, and the presence of powerful thunderstorms early each afternoon.

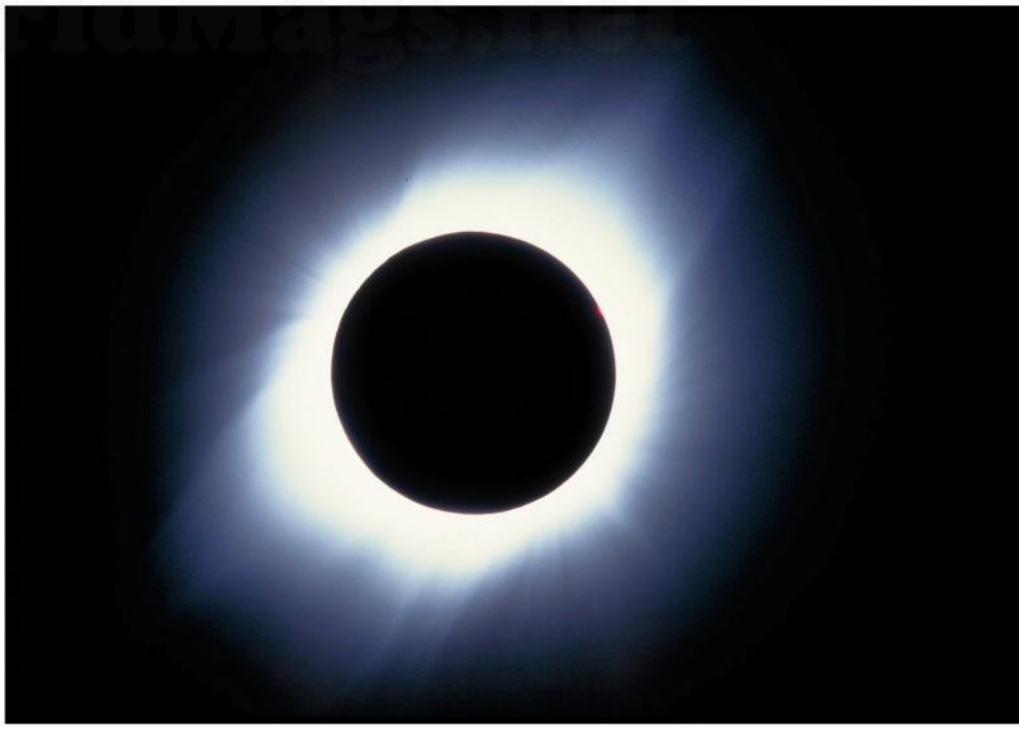
Eclipse chasers seeking clear skies will have to contend with the possibility of pesky bands of heavy, moisture-laden clouds across much of the narrow eclipse path. The best way to minimize the impact of these clouds will be to have high mobility. Because 70 percent of this eclipse occurs over open ocean waters, travelers who base themselves on cruise ships equipped with the latest weather satellite, radar, and GPS technology stand a reasonably good chance of seeing totality.

Watching from land

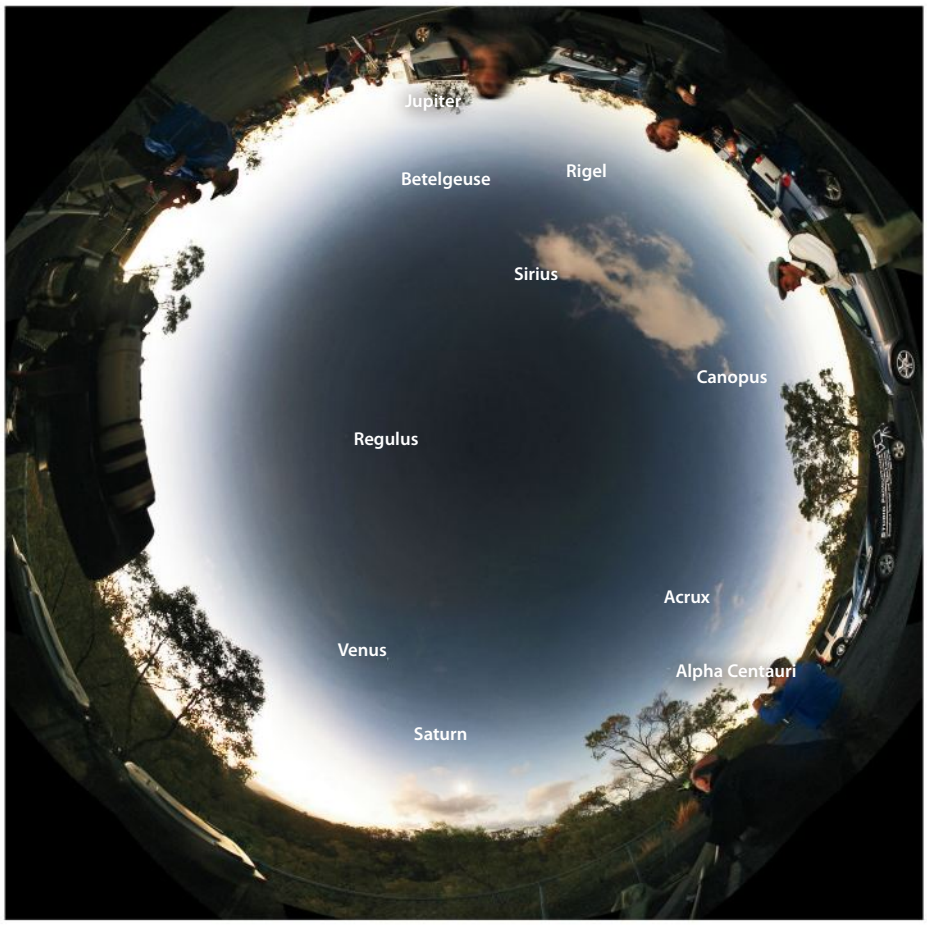
Alternatively, for those eclipse aficionados who prefer a land-based observation site, the story is not entirely dismal. The three keys to selecting a site that improves the odds of seeing the eclipse are 1) high mobility; 2) reliable, real-time meteorological images and data; and 3) a flexible — if not minimalist — observing program.

From the point where the eclipse first makes landfall, in the nation of Gabon, onward through the Democratic Republic of the Congo (DRC), then through the Congo (a separate country) and Uganda, prospects appear bleak. Experts characterize the region as having poor weather, sparse infrastructure, and difficult road conditions. Save for the coastal area of

Joel K. Harris *is a veteran of 18 total and five annular solar eclipses. He works as a staff scientist and systems engineer at Pratt and Whitney Rocketdyne in Canoga Park, California, and is the founder and president of Twilight Tours Inc., in Westlake Village, California.*

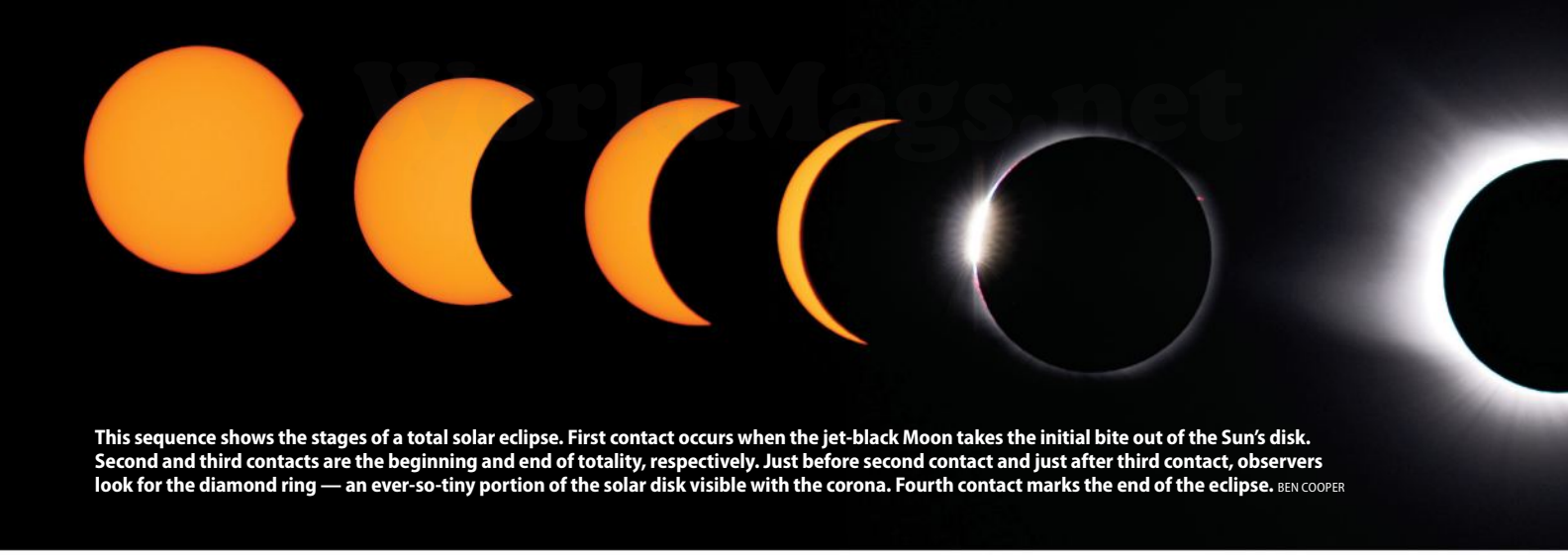


The author took this image of the solar corona (the Sun's outer atmosphere, which becomes visible during totality) February 26, 1998, from Punto Fijo on the Paraguana Peninsula in Venezuela. The only time you can safely look at the Sun without eye protection is when the corona is visible during totality. JOEL K. HARRIS



This all-sky panorama shows three planets and about 20 stars during mid-totality of the November 14, 2012, Australia eclipse. The imager created this view with a Canon EOS 5D Mark II DSLR set to ISO 400. He photographed eastern (⅛- and ¼-second exposures), northern (¼-second exposure), western (¼-second exposure), and southern (¼-second exposure) horizons, plus the overhead sky (½-second exposure), with a 17mm f/2.8 fisheye lens set to f/3.5. He then combined the views into a single image. TUNÇ TEZEL

WorldMags.net



This sequence shows the stages of a total solar eclipse. First contact occurs when the jet-black Moon takes the initial bite out of the Sun's disk. Second and third contacts are the beginning and end of totality, respectively. Just before second contact and just after third contact, observers look for the diamond ring — an ever-so-tiny portion of the solar disk visible with the corona. Fourth contact marks the end of the eclipse. BEN COOPER

Gabon between the towns of Port Gentil and Cape Lopez, traveling to an eclipse site in this region involves fording rivers or estuaries, driving on rugged dirt roads, and finding an observation site unobstructed by tall trees or heavy vegetation.

The climatological conditions improve somewhat in the interior of Gabon and the DRC. Unfortunately, in addition to the problem of mobility, the U.S. State Department has some strong words about travel to the DRC, which continues to experience significant social and economic upheaval.

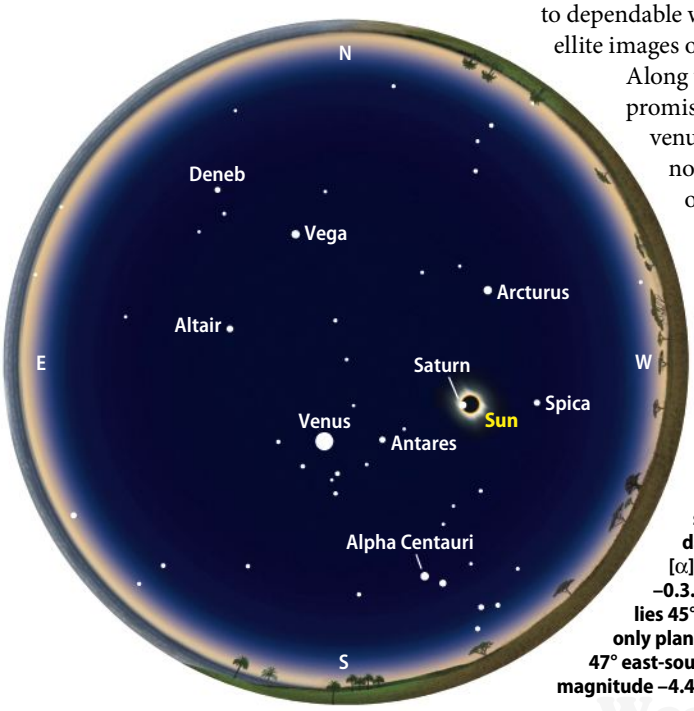
To check conditions there, I visited my colleague and fellow eclipse chaser Jay Anderson's website at www.eclipser.ca. There, anyone can access an impressive amount of historical climate information about potential observing sites along the eclipse track. Anderson specializes in providing the astronomical community with detailed, accurate, and user-friendly eclipse weather data. Initially, he did it as a working meteorologist at Environment Canada. Since retiring from the weather bureau, he now posts information as a private citizen.

According to Anderson's data, as the eclipse track enters Uganda and rapidly moves into the extreme northern portion of Kenya, southern Ethiopia, and Somalia, the weather prospects for viewing this eclipse improve. In northwest Uganda, near the town of Pakwach in the region just north of Lake Albert, the daily amount of possible sunshine at this time of year hovers around 60 percent. Compare that with averages in the 30 to 40 percent range for Gabon, the Congo, and the DRC.

But again, there are nontrivial challenges to reaching this region: finding suitable accommodations, securing reliable ground transportation, and gaining access to dependable weather news (let alone satellite images or maps).

Along with Uganda, two other promising, though hard to reach, venues exist. The first is in northern Kenya, on the shore of Lake Turkana, formerly known as Lake Rudolf. This large lake ranks as the world's largest alkaline lake, the fourth-largest salt lake, and the 24th-largest lake overall. According to historical climate statistics on Anderson's website, the weather in the area surrounding Lake Turkana is "the best land-based viewing site along the track."

Lodwar, one of the largest towns in the region near Lake Turkana, has limited tourist services. Finding suitable accommodations, supplies, and transportation will be hard for those seeking access to the eclipse center line some 37 miles (60km) from town. Thankfully, the roads connecting Lodwar, Peleketch, and Kakuma (leading into and beyond the eclipse track) are quite good. Even so, getting to the shore of Lake Turkana will be dicey because access to much of the shoreline is via dirt tracks, requiring the use of high-clearance, four-wheel-drive vehicles.



At mid-totality from the center line on the Gabon coast, the Sun will be 47° high in the west-southwest. Look 35° north of our daytime star for Arcturus (Alpha [α] Boötis) shining at magnitude –0.3. Slightly brighter Alpha Centauri lies 45° south of the Sun. Probably the only planet you'll see will be Venus. It lies 47° east-southeast of the Sun and blazes at magnitude –4.4. *ASTRONOMY:* RICHARD TALCOTT AND ROEN KELLY

Other considerations

Aside from the meteorological, access, and logistical difficulties of this eclipse, making the commitment to see it stands as a costly prospect for the eclipse chaser.

Anyone who has engaged in some form of international travel in recent years can attest to the steady increases in the price associated with journeying to far-off countries. And the cost has gone up whether you are content to join an organized tour composed of fellow eclipse enthusiasts or are a do-it-yourself (DIY) traveler who wants the freedom to construct a unique travel program for yourself or a small group.

I conducted a quick survey of several travel firms offering packaged tours to November's eclipse (both land-based or situated on a medium or large cruise vessel). It showed that the typical cost of going to the November eclipse can run from $5,000 to more than $10,000 per person for a seven- to 10-day itinerary. Also, be aware that some tours do not include air travel to



the gathering point where the tour actually begins, thereby adding yet more cost to the basic tour package.

For those taking the DIY option, you might save money by creating your own trip. That said, some of those savings could be lost because individual travelers can face difficulties when attempting to secure individual hotel accommodations, local tour-guide support, or suitable rental vehicles, given the limited inventories in the countries along the eclipse track.

Some travelers also have acquired reduced-fare international air tickets through online ticket sellers like Orbitz and Expedia, or so-called "airline consolidators" or "bucket shops." A problem you might encounter using this means to book international flights is that you must remain highly flexible. You have to be willing and able to leave on short notice when your desired flight(s) becomes available.

Author's advice

I have spent 40 years traveling to total solar eclipses around the world. That personal experience leads me to share three guidelines with those who elect to travel to this November's eclipse.

First, travel as simply as you can. Do your homework as to the anticipated local climate conditions you can expect on your trip, and only bring those items that are essential to your comfort and the formality of attire needed.

One thing you'll experience traveling with four suitcases containing dozens of fashion statements is reduced mobility. But the biggest problem is that it will cost you dearly in added baggage charges.

Second, unless you are a part of a formal research expedition, resist taking every camera, lens, piece of telescopic hardware, accessory, or computer that you have in your possession. Aside from the issue of added baggage charges (from what you put in your checked luggage), traveling through multiple airports in far-off countries, laden down with carry-on optics (too valuable or breakable to check) like a beast of burden is not fun. It gets old quickly and saps your energy in no time.

Third, make sure you have researched the documentation you will need for your trip long before it occurs. Waiting to confirm the validity of your passport, discovering that you need one or more visas to enter the country you want to visit, or learning two weeks before you go that you will need five different vaccinations to travel to your final destination will create tremendous stress — something to avoid before undertaking a protracted journey.

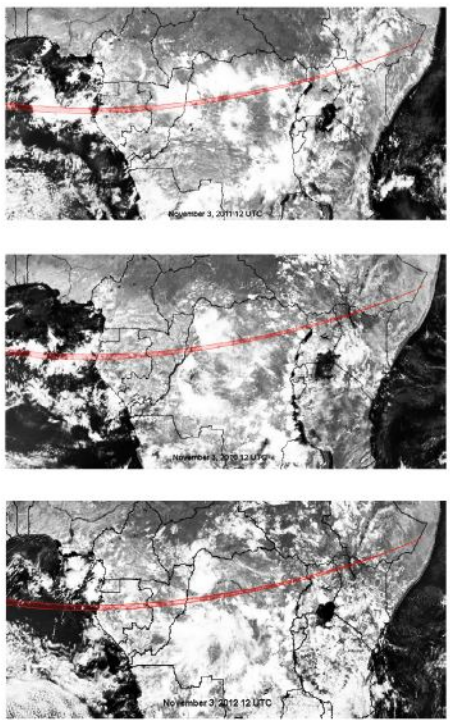
The bottom line

To summarize, the hybrid solar eclipse that will happen November 3 promises to be yet another potentially exotic, exciting, and personally rewarding astronomical treat for those choosing to travel to see it. Even after chasing 18 total eclipses in the past four decades, I still find myself getting excited — and nervous — at the prospect of again immersing myself for those precious and all-too-brief minutes in the Moon's umbra.

Despite the possible adventure, anyone considering going to this year's eclipse needs to carefully weigh each aspect I discussed: the probability of success, the effort required to travel to your chosen observation site, and the costs involved in making such a journey.

The odds are about 50/50 that if you elect to expend the time and money to travel to the event, you will catch some glimpse of it. Those certainly are much better odds than you'll find in any casino. And apart from the celestial event, consider this an opportunity to travel to any one of a number of "off the beaten path" countries in sub-Saharan Africa. You'll see that this eclipse has a lot going for it.

Whatever you finally decide, I want to wish everyone journeying to observe the coming eclipse safe travels, good luck, and clear skies.



ALL IMAGES COPYRIGHT 2013 EUMETSTAT

These satellite images show the cloud cover over the land portion of the eclipse path as it appeared November 3 during 2010 (top), 2011 (middle), and 2012. The time of these images is 12h UT, which is approximately two hours before the Moon's shadow makes landfall in Gabon this year.

VIEW A TOTAL SOLAR ECLIPSE PHOTO GALLERY AT **www.Astronomy.com/toc.**

WorldMags.net

WorldMags.net

Associate Editor **Sarah Scoles** *takes a ride with SOFIA, a telescope that always flies first class.*

A field trip to the

Astronomers will go to great lengths — and heights — to use telescopes. I saw that firsthand in June, when I stowed away on the Stratospheric Observatory For Infrared Astronomy (SOFIA), a Boeing 747 jet modified to house an infrared telescope. By "modified," I mean that it has 4,000 extra sensors, miles of new cable, and a hole in its fuselage where the telescope can see out. It looks up to space from the stratosphere, 40,000 feet (12,200 meters) above sea level and just above the water-logged troposphere.

The journey began in Palmdale, California, a city in the Mojave Desert's Antelope Valley. Here, aerospace giants like Lockheed Martin, Boeing, and the federal government — in the forms of the Air Force and NASA — have bases. At the Dryden Aircraft Operations Facility, a hangar holds numerous aircraft, including SOFIA, that NASA has tailored to Earth- and space-science purposes. Scattered amid the planes and toolboxes are dozens of seats with outdated upholstery, removed to make room for radar transmitters and racks of circuit boards. But why does NASA need to gut planes and stick electronics on them?



Astronomy **Associate Editor Sarah Scoles (center) and science teachers John Clark and Anne Smith board SOFIA for a science flight.** PAMELA HARMAN

SOFIA's rise to power

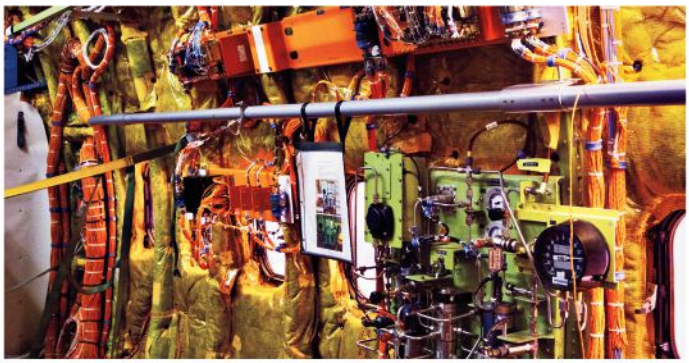
Infrared telescopes need to be above the lower atmosphere, where water blocks this wavelength band, which is less energetic than visible light. The troposphere's impermeability is good for global warming but bad for astronomers. So some infrared scopes sit atop mountains, and some are in orbit. But SOFIA scientists said, "Why only go either halfway or so far away?"

They decided to rise above the water in style — specifically, on a former Pan Am 747 christened the *Clipper Lindbergh* on the 50th anniversary of Charles Lindbergh's solo flight across the Atlantic.

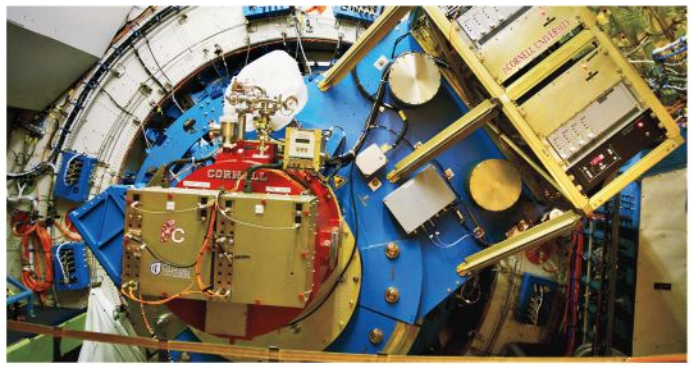
NASA bought the plane in 1997. Partnering with the German Aerospace Center and the Universities Space Research Association, the agency spent 10 years building a 2.5-meter telescope that can focus on a fixed point while traveling 500 mph (800 km/h) and a jet door that opens mid-flight without asphyxiating technicians or sending SOFIA into a tailspin.

In 2009, the plane first flew with its door ajar. Edward Zavala, the program manager, feared the project would end that day. "The wind could have turned it into a giant organ pipe," he says. "That would have exhausted the plane's fatigue life in just 20 minutes." It would have been useless.

Luckily — or, rather, through simulations and precise engineering — the door



The SOFIA 747 has miles of new cable, thousands of new sensors, and many fewer creature comforts than it had when it was a commercial jet, as it was from 1977 to 1997. SARAH SCOLES



The Faint Object infraRed CAmera for the SOFIA Telescope (FORCAST), which scientists at Cornell University created, mounts on a tube that connects the pressurized cabin with the cold, depressurized telescope area. SARAH SCOLES

WorldMags.net

stratosphere



The door in the Stratospheric Observatory For Infrared Astronomy's (SOFIA) fuselage opens to reveal an infrared telescope that observes objects in space while the 747 is flying through the stratosphere. The setup is safe at up to 48,000 feet (14,600 meters) above sea level. NASA/TOM TSCHIDA

opened and later shut, with nothing bad happening in between. The telescope saw first light in 2010.

SOFIA had just taken its 100th flight when Anne Smith of Green Bank, West Virginia, John Clark of Deltona, Florida (both science teachers), and I arrived as Airborne Astronomy Ambassadors. We were granted seats on board so that we could bring SOFIA's science to students and the story to our readers on the ground. But before we could share our experiences, we needed to learn about three-point harnesses, oxygen-dispensing devices, and the inflatable emergency slide — everything you would hear in the exit row of a commercial craft, just slightly "modified."

Systems Engineer Marty Hench gave us an extra tip. "There's a door in the floor of the cabin," he said. "We call it the hell hole. It's the fastest way to the ground."

At the mission briefing, which included the whole crew of 26, Mission Director Nancy McKown displayed the flight path. A roomful of blue and brown NASA jumpsuits surveyed the zigzag from California to Arkansas to Wyoming and, 10 hours after takeoff, right back to the Palmdale facility. We would be flying from 7:30 P.M. to 5:20 A.M. PDT. "Please expedite climbs when possible," McKown said to the pilots. More time for science.

Sarah Scoles *is an associate editor of* Astronomy *and a frequent flyer.*

All aboard

Sandwich and 16 ounces of energy drink in hand — no in-flight meals or coffee here — I boarded and donned a headset. With little tapestry to absorb sounds of rushing air, this was the best way to communicate.

Smith and Clark slid their headsets on, too, and we tuned to all available channels: the scientists' ("Is that graph supposed to look like that?"), the engineers' ("We're going to have to reboot"), and the pilots' ("That's restricted airspace").

That night, SOFIA was hooked up to the Faint Object infraRed CAmera for the SOFIA Telescope (FORCAST), one of nine first-generation instruments, each of which can be snapped on and off like LEGOs. While the telescope is in a sealed-off section of the airplane, a tube tunnels through the bulkhead, connecting the telescope to the world of the living and to the instrument that actually processes and records the data.

SOFIA, which uses mirrors like an optical telescope, directs infrared rays through the tube and onto the detector, which functions like the CCD chip on a digital camera. The digitized information then travels to computers that process and display it so the team can watch for anomalies that suggest a malfunction.

Gyroscopes, cameras, and magnetic torque motors determine whether the telescope is pointing at the right spot. Engineers adjust its position in real time, as it bobs on bearings that float atop pressurized oil, a system that inoculates the scope against coach-class vibrations.

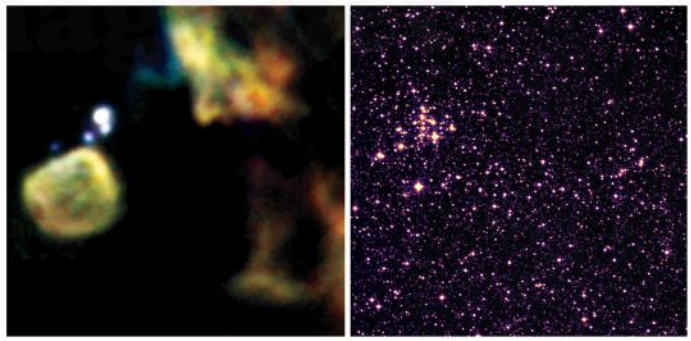
While Smith, Clark, and I sat fiddling with our harnesses and going over how the portable oxygen hoods worked, the telescope's private chamber was being cooled to match the frigidity of the high-altitude world it would soon meet.

Chatter dropped off as we listened to the pilots run checklists and negotiate our takeoff with ground control. When we lifted off, the climb did feel expedited, and the "fasten seat belt" sign blinked off quickly, allowing me to kneel next to exposed wires and plaster my face against a thick window.

WorldMags.net



Cornell University scientists, including Ryan Lau (right), fix any problems that arise with the Faint Object infraRed CAmera for the SOFIA Telescope. SARAH SCOLES



NASA/DLR/USRA/DSI/FORCAST (INFRARED); NASA/HST/STSCI/AURA (OPTICAL)

When SOFIA looks at the Quintuplet Cluster, a group of stars forming together in Sagittarius, the telescope sees dust cocoons and forming stars (left). Dust blocks much of the visible light, so the Hubble Space Telescope is unable to see many of the features that come through in infrared light (right).

Sunset in the stratosphere

As the Sun set and SOFIA ascended, we could see the line ending the chaotic troposphere — where water and heat rule the dynamics — and beginning the stratosphere — a cool, calm, dry place. The boundary, called the tropopause, can be as low as 30,000 feet (9,100m) above sea level at the poles; at the equator, it rockets up to 56,000 feet (17,000m). At mid-latitudes, where we were, the tropopause is usually around 40,000 feet (12,200m), a mile or two above normal cruising altitude. On a clear day (which is every day in the stratosphere), you can see forever and tell that all the weather-related action is below you.

When SOFIA reached its target altitude, the plane turned to a different "heading," the straight path that keeps a target perpendicular to the telescope. McKown confirmed that observations could begin.

"The door is open," she said.

"Can you tell?" asked Smith. "I can't tell."

We had our own bank of computers that showed the telescope's status and a visible-light view of what SOFIA saw in infrared. If SOFIA was tracking a target, we saw a still star or gas cloud. But if the telescope was not locked on, we saw stars "streaking and slipping by," as Hench said, like a sci-fi trip through hyperspace.

SOFIA's sights

That night, SOFIA was all about dust. Dusty areas of space are usually in the middle of doing something, like forming stars, planets, or complex molecules. These regions will later be cleaned up, as stars blow debris away or planets sweep it up in their orbits. But SOFIA peers into places that visible light can't penetrate (imagine seeing in a room filled with flying dust) and observes objects while they're still gestating.

While we were aboard, SOFIA searched for polycyclic aromatic hydrocarbons — organic molecules that are biological precursors — in distant Milky Way clouds to better recognize them in more-distant galaxies. The telescope slewed to stars forming in a cluster and then watched jets shooting from high-mass almost-stars called "young stellar objects." An astronomer had proposed each project, and a team of experts had deemed the work worthy of covetable flight time. Whenever the telescope switched to a new astronomer's project, the plane turned abruptly and ascended or descended to meet the tropopause, staying always just above the disruptive moisture.

Through the night, Cornell University graduate student Ryan Lau was glued to his computer, analyzing data as it came in and making sure FORCAST was behaving. When it wasn't, a team member jumped into the software files and rewrote code. While this is always difficult, it's especially so at 5 A.M. when you've been breathing recycled air for eight hours.

The perfect job?

Just before sunrise, everyone was a little punchy. The astronomers discussed their lack of knowledge of constellation boundaries. Smith and I thumbed through the mission-jargon dictionary, citing "attitude control computer," which automatically keeps the scope oriented, and "flexible body compensation," which is SOFIA's version of adaptive optics, as favorites.

James De Buizer, a SOFIA instrument scientist, was displeased with a calibration problem that had popped up during the flight. "You're just a ray of sunshine," another scientist said.

"Is realism a ray of sunshine?" De Buizer asked. "If so, then yes."

But you have to be a realist if you want to cut a hole in a jet, fly into the stratosphere, and return with both data and a live crew. SOFIA was built by realist-dreamers who could imagine the technology but also assemble the team to build it — flight mechanics, mechanical engineers, electrical engineers, software engineers, safety technicians, pilots, astronomers, and many more. They come from military, academic, governmental, and industrial backgrounds. They come from Palmdale and San Francisco and Iowa City. They each know different nuts and bolts of SOFIA, and together, they have assembled those parts into a functional flying observatory.

"I pinch myself when I come to work," said Hench just before touchdown. "Look at my office."



After deplaning and before heading to bed, the SOFIA Airborne Astronomy Ambassadors pose with some of the crew members, pilots, and astronomers that made their flight and the night's important astronomical research possible. NASA/CARLA THOMAS

SEE MORE IMAGES FROM INSIDE SOFIA AT **www.Astronomy.com/toc.**

NEW PRODUCTS

Attention, manufacturers: To submit a product for this page, email **mbakich@astronomy.com**.



3-inch telescope



Celestron
Torrance, California
Celestron's Cometron First-Scope is a tabletop 3-inch f/4 Dobsonian-style telescope. It weighs only 4.3 pounds (2 kilograms). The company includes a 5x24 finder scope and 10mm (30x) and 20mm (15x) eyepieces.
Price: $59.95
[t] 310.328.9560
[w] www.celestron.com

Hand focuser



JMI Telescopes
Lakewood, Colorado
JMI's MOTOFOCUS for iOptron MC90 eliminates the need for hand focusing. The modulated hand unit allows incredibly small and precise movements of the motor. JMI constructed the focuser from brass and steel. It installs in one minute.
Price: $179
[t] 800.247.0304
[w] www.jmitelescopes.com

CCD camera



Point Grey
Richmond, Canada
Point Grey's Grasshopper3 GS3-U3-60S6 CCD cameras contain a 1-inch Sony ICX694 chip. The camera can send 2736x2192 images at 13 frames per second. It features a USB 3.0 interface. Color and monochrome versions are available.
Price: $3,495
[t] 604.242.9937
[w] www.ptgrey.com

8-inch reflector



Orion Telescopes & Binoculars
Watsonville, California
Orion's SkyQuest XT8 PLUS Dobsonian Reflector Telescope has a thumbscrew-adjustable secondary mirror, a 2" dual-speed focuser, and adjustable altitude tension knobs. The scope comes with 10mm and 28mm eyepieces.
Price: $499.99
[t] 800.447.1001
[w] www.telescope.com

7x50 binoculars

Celestron
Torrance, California
Celestron's Cometron 7x50 binoculars offer multicoated optics, a rubberized aluminum housing, a neck strap, lens and eyepiece caps, and a carrying case. The unit provides a 6.8° field of view, eye relief of 13 millimeters, and a 7.1mm exit pupil. The binoculars weigh 27.3 ounces (774 grams).
Price: $34.95
[t] 310.328.9560
[w] www.celestron.com

Truss system



New Moon Telescopes
West Monroe, New York
New Moon Telescopes' Collapsible Truss System connects the upper cage of a Dobsonian-mounted reflector to the mirror box with a folding truss. Hand screws are large enough for you to tighten or loosen with gloves on.
Price: $298 (without truss poles)
[t] 315.430.8730
[w] www.newmoontelescopes.com

SEE REPORTS ON 300+ PRODUCTS AT **www.Astronomy.com/equipment.**

Get **MORE** from your magazine!



Take advantage of all the online features *Astronomy* has to offer:

- Post comments on blogs & forums
- Submit and comment on astro photos
- Receive our free weekly newsletter
- AND MORE!

It's FREE to sign up!

Find out more at:
www.Astronomy.com/Join

P17536

WorldMags.net

Travel to deep space in 2014!



NEW for 2014!

Your thrilling trip includes:

- 12 stunning images and descriptions of deep space objects
- Noted major milestones in astronomy and space exploration
- Key celestial viewing opportunities for each month

PLUS — get a bonus overview of the constellations!

BOARD TODAY AT YOUR NEAREST HOBBY SHOP!

To find a store near you, visit wwwHobbyRetailer.com

OR VISIT www.KalmbachStore.com

OR CALL 1-800-533-6644

Monday – Friday, 8:30 a.m. – 4:30 p.m. CST.
Outside the United States and Canada call 262-796-8776, ext. 661.

KB KALMBACH BOOKS

#68172 • $12.95

WorldMags.net

P20553

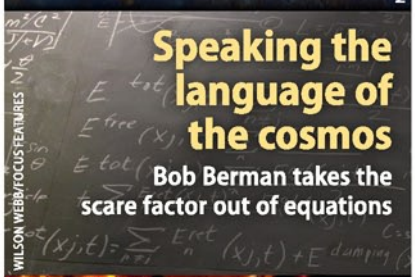
2A2016

COMING IN OUR
NEXT ISSUE

Torrid
Mercury's ice poles

The MESSENGER spacecraft reveals water ice lurking in deeply shadowed craters near the innermost planet's poles





Speaking the language of the cosmos

Bob Berman takes the scare factor out of equations



Spacecraft: Where are they now?

What happens after planetary missions end?

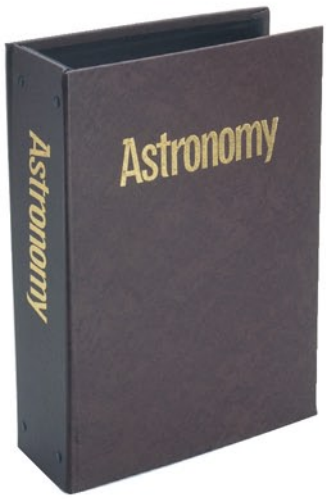
PLUS

- Behind the scenes at Celestron
- Comet ISON's dazzling all-night show
- How an amateur astronomer made his dream observatory
- 11 top winter binocular gems
- Grab a Cometron scope to view Comet ISON

Astronomy magazine

PROTECT YOUR INVESTMENT!

Preserve your library of *Astronomy* magazines with durable hardcover binders.



Order yours today!

ITEM NO. 14007
1 for $13.95
3 for $38.95
5 for $59.95

call 1-800-533-6644

Mon–Fri, 8:30 a.m.–4:30 p.m. Central Time.
Outside the U.S. and Canada, call 262-796-8776.

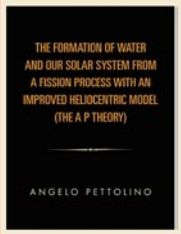
www KalmbachStore.com

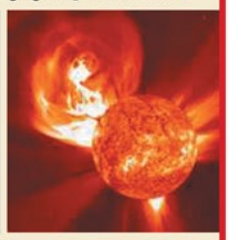
Astronomy

PMK-ADH-09X1462RH A2002

The Formation Of Water And Our Solar System From A Fission Process With An Improved Heliocentric Model (The AP Theory)

$80.00 Hardcover • $60.00 Softcover
23 original 4-color high gloss prints included.





SATISFACTION GUARANTEED
E-book from Xlibris

THE ONLY COMPREHENSIVE DESCRIPTION OF THE FORMATION OF WATER FROM GAS EVER PUBLISHED.
Some of the most fundamental questions about the formation of water and our solar system are logically answered for the very first time in this new, non-fiction, cutting edge, easy to understand book. The AP Theory is the most provable, must read book that directs our minds down new paths describing water and our solar system's formation. The AP Theory is the logical answer to the fundamental questions: how was water and our solar system formed? Grounded in science; it dispels the many myths and misconceptions surrounding water and our solar system's formation with a definitive description and chronological interpretation.

This easy to read, essential book is a welcome addition to the information presently being offered as fact. There weren't any "water from gas" formation theories until now and scientists admit they haven't a clue as to how water formed. The AP Theory is the only theory which satisfactorily describes exactly when and how hydrogen and oxygen gases became water and where and how the heat and pressure necessary to forge the gases into water (H_2O) originated. The AP Theory turns the astronomy community on its ear by presenting questions which severely cloud the creditability of the accretion (theory) process and by presenting compelling evidence, to discredit the "gravitationally held (gas) atmosphere" theory. Internationally acclaimed for its controversial, courageous and "bold truth" statements this one of a kind, watershed book advances cosmology and science to a new level of enlightenment by using the latest scientific discoveries to help prove its position. The AP Theory supersedes the present texts and library reference books.

www.aptheory.info • Barnesandnoble.com

Amazon.com • orders@xlibris.com.au

Volume Discounts library & school sales
aptheory@aptheory.info

STARMASTER PORTABLE TELESCOPES
Hi Performance Dobs. Truss Mounted Scopes ranging in sizes from 8" up to 28"
2160 Birch Rd. • Arcadia, KS 66711
or Call: (620) 638-4743
9:00 am-9:00 pm C.S.T 7 days a Week.
www.starmastertelescopes.com



ASTROFACTORS
Astronomical CCD Cameras!
Come check out our new cameras!

The new **QHY5I-II**



- Autoguider
- Planetary Camera
- Very High Sensitivity Qe 74%

$320.00

The new **QHY22** Mono, 6 Megapixel



- Low noise Mono with the Sony ICX694 CCD
- Qe of 77%
- QHY filterwheel included

$2699.00

www.astrofactors.com 214 764 1323

CPU by Bob
Custom astronomical and gaming computers made with customer consultation and approval
questions@cpubybob.com | facebook.com/cpubybob
(570) 352-3079

Deep-Sky Planner 6
comprehensive planning & logging software • latest object data • telescope control • chart interoperation
Astronomy magazine 2013 Star Products
www.knightware.biz

Destiny®



1800DESTINY produces the best Curved Vane Telescope Spiders available
1-800-337-8469
Email: hans@1800destiny.com



Bob's Knobs
Meade, Celestron, Intes, Takahashi . . . and more!
6976 Kempton Rd.
Centerville IN 47330
765-855-5109 USA
www.bobsknobs.com

OPTIC WAVE O.W.L. LABORATORIES
Optical Coatings
Parabolic Mirrors
Testing
Refiguring
www.OpticWaveLabs.com



OBERWERK
Astronomical binoculars and binocular telescopes at down-to-earth prices.
Astronomy 2013 Star Products
BT-100-45
BT-70-45
Available exclusively at
www.bigbinoculars.com
Toll-free 866-OBERWERK
1861 Wayne Ave., Dayton, OH 45410

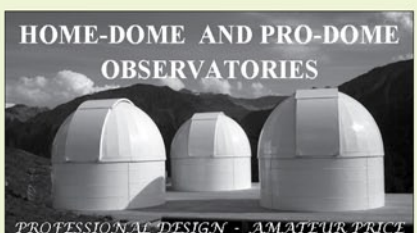




MILKY WAY BY TONY HALLAS

STELLARVUE®
WWW.STELLARVUE.COM
11820 KEMPER ROAD
AUBURN, CA 95603
(530) 823-7796

HOME-DOME AND PRO-DOME OBSERVATORIES



PROFESSIONAL DESIGN - AMATEUR PRICE

★ 6, 10, & 15 ft. Diameter
★ Stand-alone or On Building
★ All Fiberglass
★ Easy Assembly
★ Manual/Computer Automated
★ Full Height/Handicap Access
★ Priced from $3,295

CloudWatcher
Low cost, accurate system to detect cloud cover, light levels and first traces of rain. With DDW interface.
www.clouddetection.com

Call or write for FREE Brochure
TECHNICAL INNOVATIONS
• Phone: 301-977-9000 • FAX: 301-977-1106 • www.homedome.com

Keeping it "Beautifully" Simple
Almost Zero Add-Ons... Robotic right out of the box
Almost Zero Installation... Takes hours not months



domesales@astrohaven.com
949.215.3777 www.astrohaven.com

Howie Glatter's Laser Collimators & Accessories
tuBlug ™ and Blug™ Barlowed collimation aids
- SkyPointers™ & brackets
- Glatter Mirror Sling kits



The Parallizer™
2"-1.25" adapter for Perfect Parallel Alignment
Howie Glatter 3850 Sedgwick Ave. Bronx, N.Y. 10463
Tel/Fax (718) 796 3203
www.skypointer.net www.collimator.com
e-mail: howieglatter@mindspring.com

Mechanical Paradox Orrery
Invented in 1750 by the Scottish astronomer James Ferguson
Email sales@armstrongmetalcrafts.com
for Astronomy subscriber pricing



ARMSTRONG METALCRAFTS
CURIOSITY | CREATIVITY | CRAFTSMANSHIP
WWW.ARMSTRONGMETALCRAFTS.COM

See the Universe in color live with
MALLINCAM™
Astronomical Video CCD Cameras
MALLINCAM.COM

ECLIPSE SHADES™
Safe Solar Viewers
CE Certified
SAFE FOR DIRECT SOLAR VIEWING



Rainbow Symphony, Inc.
818-708-8400 • Fax 818-708-8470
www.rainbowsymphony.com



Copyright Tony Hallas

Simplify your CCD imaging
- Tru-Balance LRGB imaging filters
- 3 and 5 nm narrowband filters (H-a, OIII, SII, NII)
- 100% coated Sloan & UVBRI photometric filters
- MOAG, MonsterMOAG off-axis guiders
- TAKometer remotely-controlled camera rotator

Astrodon® www.astrodon.com

Shelyak INSTRUMENTS
Stars won't look the same
LISA Pack
Spectroscopy made easy...



www.SHELYAK.com

ScopeStuff
Telescope Accessories & Hardware
World's largest inventory of telescope accessories, adapters and hardware. **Free shipping in the USA!**
www.scopestuff.com
512-259-9778

ASTRO-PHYSICS
Instruments for discriminating observers and astro-imagers
Telescopes — GoTo German Equatorials
Visual and Photographic Accessories
Unparalleled Service and Support
Dedicated to
Craftsmanship!



New!!!
1600GTO
Absolute Encoders (optional)
www.astro-physics.com
11250 Forest Hills Road
Machesney Park, IL 61115, USA
Ph: 815-282-1513, Fax: 815-282-9847

The Most Complete Telescope Store in Texas
Authorized dealer:
Celestron, Orion, Tele Vue, Meade, Vixen, Fujinon, Vortex, Home-Dome, Books, Charts, Software
Service • Repairs
Private lessons
FREE instruction at night with every telescope purchase



The Observatory, Inc.
17390 Preston Road #370
(Two traffic lights north of Campbell Rd.)
Dallas, TX 75252 (972) 248-1450
www.TheObservatoryInc.com

THE NINE PLANETS RING
HANDCRAFTED WITH AN ORBITING GIBEON METEORITE BAND IN 18K GOLD SET WITH 9 GEMSTONES



JEWELRYDESIGNSFORMEN.COM
831.336.1020

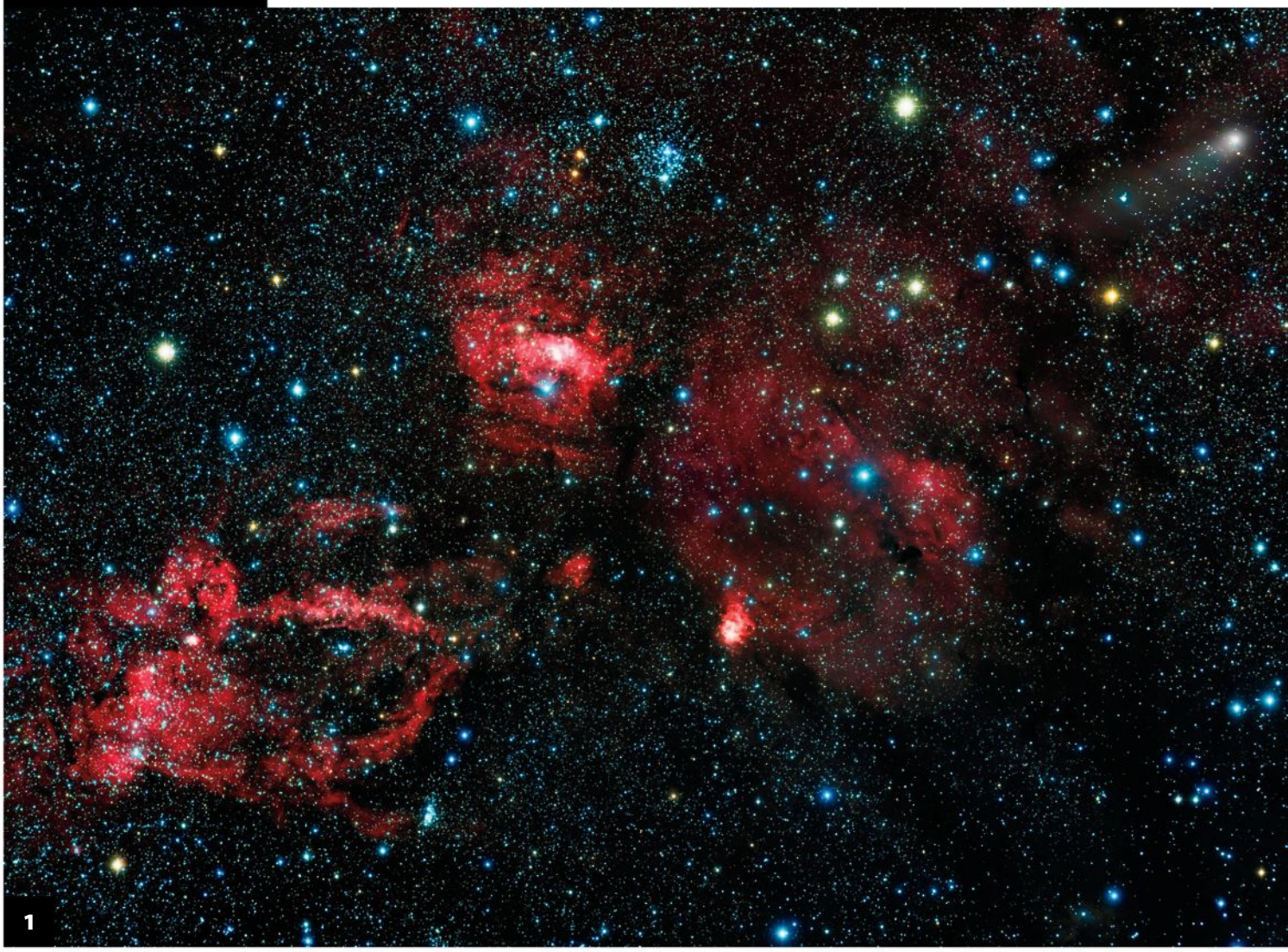
INDEX *of* ADVERTISERS

1-800 Destiny 70
ADM Accessories 70
Adorama 15
AP Theory 69
Arizona Science & Astronomy Expo 22
Armstrong Metalcrafts 71
Ash Manufacturing 17
Astro Factors 70
Astro Haven 70
Astro-Physics 71
Astrodon 71
Astronomics 17
Astronomy Binders 69
Astronomy Calendar 68
Astronomy magazine 67
Astronomy Special Issue 8
Bob Berman Tours 17
Bob's Custom Computers 70
Bob's Knobs 70
Cambridge University Press 19
Celestron 3, 5, 23
Chroma Technology 23
Deep Space Products 23
Explore Scientific 19
Glatter, Howard 71
ISTAR Optical 70
Jewelry Designs For Men 71
Knightware 70
Lunt Solar, LLC 23
Meade Instruments Corporation 76
Moonglow Technologies 19
National Science Foundation 2
Planewave 23
Poly Dome 23
Procom Electronics 71
Observadome Laboratories 21
Observatory Inc., The 71
Obsession Telescopes 70
Oceanside Photo & Telescope 21
Optic Wave Laboratories 70
Orion Telescopes & Binoculars 7
Rainbow Symphony 71
Santa Barbra Instrument Group 20, 23
Scopestuff 71
Shelyak Instruments 71
Sky-Watcher USA 23, 75
Skylight Refractors 19
Software Bisque, Inc. 23
Starmaster Portable Telescope 70
Stellarvue 23, 70
Technical Innovations 70
Tele Vue Optics, Inc. 19, 23
TravelQuest International 21
Vixen Optics 23
Woodland Hills Cameras & Telescope 13
www.bigbinoculars.com 70

The Advertiser Index is provided as a service to *Astronomy* magazine readers. The magazine is not responsible for omissions or for typographical errors in names or page numbers.

WorldMags.net

WorldMags.net



1. A SURPRISE CATCH
After the imager captured this region of Cassiopeia that he dubbed the "Cosmic Garden," he noticed Comet Lemmon (C/2012 F6) at the upper right. Comet Lemmon approached closest to the Sun on March 24, at the time shining at 5th magnitude. (3.6-inch Thomas M. Back TMB92SS refractor with Teleskop Service 2.5" Flattener, QHY CCD QHY11 CCD camera, HαRGB image with exposures of 240, 90, 90, and 90 minutes, respectively, taken July 14/15, 2013, from Fremont, Michigan) • ***Terry Hancock***



2. THE SKY OVER MINYA KONKA
The Milky Way stretches above Minya Konka, the highest mountain in China's Sichuan province. Also known as Gongga Shan, the summit of "The King of the Sichuan Mountains" reaches 24,790 feet (7,556 meters) above sea level. (Canon EOS 5D Mark II DSLR, AF-S Nikkor 14–24mm f/2.8G IF–ED lens set at 16mm and f/2.8, Lee Soft Filter No. 2, ISO 2500, 77-second exposure) • ***Jeff Dai***

WorldMags.net



3. THE PADLOCK

Planetary nebula Abell 36 lies in the constellation Virgo the Maiden, and it's not bright. Its central star glows at magnitude 11.5. Because of its appearance on images, the photographer has dubbed it the "Padlock." (6-inch Explore Scientific David H. Levy Comet Hunter at f/4.8, forty-eight 5-minute exposures at ISO 800 through a Canon 350D DSLR stacked with ten 10-minute exposures at ISO 1600 through a Canon T2i DSLR) • ***Chuck Kimball***





4. VENUS BUZZES M44

Imagers often catch Venus or other bright planets near the Moon. It's tough, however, to capture the third-brightest celestial object together with a fainter deep-sky object. Here, the background stars are the Beehive Cluster (M44) in the constellation Cancer the Crab. The photographer reduced the contrast between the planet and the cluster by shooting during twilight. (Canon 6D DSLR, 400mm lens at f/7, ISO 3200, 0.3-second exposure, taken July 3, 2013, from Buenos Aires, Argentina) • ***Luis Argerich***

5. STARBURST GALAXY

NGC 2782 lies approximately 110 million light-years from Earth in the constellation Lynx. It shows the result of the collision between two galaxies of unequal mass about 200 million years ago. The merger led to a wave of star formation within the galaxy. (14.5-inch RC Optical Systems Ritchey-Chrétien reflector at f/8, Apogee U16M CCD camera, LRGB image with exposures of 360, 180, 140, and 180 minutes, respectively) • ***Mark Hanson***



6. A TRIAD OF PLANETS

In late May, Venus (lower right), Jupiter (lower left), and Mercury gathered to form a brilliant celestial trio in the northwestern sky after sunset. On this night, Venus and Jupiter were a scant 1.2° apart, while the separation between Venus and Mercury was 2.3°. (Nikon D7000 DSLR, Nikon 70–300mm f/4.5–5.6 lens set at 116mm and f/5.6, ISO 400, 1/15-second exposure, taken May 27, 2013, at 9:09 P.M. MDT, from Mead, Colorado; spikes generated using the ProDigital Software StarSpikes Pro 2 plugin in *Photoshop*) • ***Richard McCoy***

Send your images to:
Astronomy Reader Gallery, P. O. Box 1612, Waukesha, WI 53187. Please include the date and location of the image and complete photo data: telescope, camera, filters, and exposures. Submit images by email to readergallery@astronomy.com.

WorldMags.net



ESO/DIGITIZED SKY SURVEY 2

Previously unseen ribbons of dust attached to the Orion Nebula

The Orion Nebula (M42) is one of the all-time all-stars of the sky. Ask just about any night-sky observer, and it'll be on their list of favorite targets, whether by naked eye, binoculars, or telescope. We have all seen images of it so many times before that we figure nothing new and interesting will ever show up, right?

Not so fast. A new image from the European Southern Observatory's Atacama Pathfinder Experiment (APEX) in Chile shows otherwise. The overexposed form of the Orion Nebula appears near the top of the image. But a deep ribbon of dust, visible in the submillimeter wavelengths of the image, appears attached to M42 and betrays the presence of tiny dust grains that shine at temperatures only a few degrees above absolute zero.

COMET ISON IS HERE!
ARE YOU READY?



Esprit Triplets
80 to 150mm
Starting at $1,649



ProED Doublets
80 to 120mm
Starting at $649



Collapsible Dobsonians
8- to 16-inch
Starting at $449

BE READY FOR THIS ONCE-IN-A-LIFETIME EVENT WITH A SKY-WATCHER USA TELESCOPE

The sky is always a fascinating place. But from November through January, Comet ISON is making it that much more so. So there's no better time to get the telescope you've always wanted. At Sky-Watcher USA we have complete lines of Dobsonian and apochromatic doublet and triplet refractors.

Our Esprit triplet apo refractors are precision crafted with the finest ED glass available. With performance equal to telescopes costing thousands of dollars more, these research-grade scopes deliver breathtaking, rich, color-free images. If you're looking for a telescope that's the equal of the best astrographs on the market, then look no further.

Sky-Watcher USA ProED refractors provide the finest viewing obtainable in their design class. These doublet refractors deliver dramatic coal-black skies and faithful, contrast-rich views of planetary and deep-space phenomenon that are second to none. ProED refractors are the logical choice for the discriminating amateur astronomer looking for an investment in advanced instrumentation for exceptional viewing.

Our Dobsonian telescopes deliver high-quality optics, huge aperture, solid construction and superb value. And only Sky-Watcher USA Dobsonians provide the extra portability and convenience of collapsible optical tubes. If you're looking for a big light bucket with a little price tag, this is the telescope for you.

Be prepared. Don't miss out on what could be the comet of the century.

AWB
Astronomers Without Borders

Sky-Watcher USA is a proud supporter of Astronomers Without Borders.

©2013 Sky-Watcher USA. Specifications subject to change without notice. 20-13019.
We're looking forward to heading out to the desert for a couple of days to do some imaging of Comet ISON. If you do the same, email us (support@skywatcherusa.com) your best shots and we'll put them up on our web site.

Sky-Watcher® USA
Be amazed.

For information on all of our products and services, or to find an authorized Sky-Watcher USA dealer near you, just visit **www.skywatcherusa.com**.
Don't forget to follow us on Facebook and Twitter!

WorldMags.net

"UNBELIEVABLE"
"INCREDIBLE"
"WOW"

THERE'S A LOT YOU CAN SAY ABOUT SOLARMAX II. AND ABOUT THE VIEW IT DELIVERS.

From the compact 40mm PST (Personal Solar Telescope) to the research-grade SolarMaxII 90, there's a Coronado scope for you.

The Coronado SolarMax H-alpha solar telescopes have long been recognized as the premier solar instruments for the amateur and professional for years. With the introduction of the SolarMax II with patented RichView™ tuning, the best is even better. The RichView™ tuning method works by directly tuning the etalon, the heart of the Coronado Ha filter system, which gives you greater tuning range and detail than that found on other solar telescopes.

You can easily zero in on precise wavelengths of light for each area of interest for the highest contrast views of active regions, flares, filaments and other surface features or for spectacular images of prominences on the solar limb. With prices for Coronado starting lower than ever, these amazing solar telescopes are within the reach of even the casual observer.

For more information on the whole Coronado line of solar telescopes, visit meade.com/coronado..



SolarMaxII 90 from $3,599



SolarMaxII 60 from $1,299



PST (Personal Solar Telescope) from $699

Optics Planet	OPT Telescopes	B & H Photo	Telescopes.com	Woodland Hills	Adorama	Canada • Khan Scopes
800.504.5897	800.483.6287	800.482.8143	800.303.5873	888.427.8766	800.223.2500	800.580.7160

©2013 Meade Instruments Corp. All rights reserved. 30-13048 Solar image shown taken through a Coronado SolarMax 90.

MEADE® INSTRUMENTS

Innovative products for curious minds | *since 1972*

WorldMags.net

MARTIN GEORGE describes the solar system's changing landscape as it appears in Earth's southern sky.

January 2014: Jupiter at its best

For the first time in 13 months, **Jupiter** reaches opposition and peak visibility this month. The solar system's largest planet achieves this pinnacle January 5, though you will have difficulty seeing much change in its appearance by month's end. You can find the giant world shining brilliantly, at magnitude –2.7, in the northeastern sky as twilight starts to fade. Jupiter resides among the background stars of Gemini the Twins, above the constellation's brightest stars, Castor and Pollux. The planet moves westward against the starry backdrop during January and, by month's end, it stands nearly midway between the two rows of stars that mark the Twins' bodies.

Although Jupiter lies well north of the celestial equator, it climbs at least 30° above the northern horizon for most Southern Hemisphere observers when it peaks around midnight local daylight time. That's the best time to observe the planet through a telescope because its light then passes through the least amount of Earth's turbulent atmosphere.

During moments of good seeing, details stand out on a disk that reaches 47" across at opposition. Any telescope reveals two parallel dark belts, one on either side of a lighter equatorial zone. Larger apertures show a series of alternating belts and zones as well as smaller features in the planet's massive atmosphere.

Around the time Jupiter peaks in the north, **Mars** pokes above the eastern horizon. The Red Planet becomes more prominent as it climbs higher during the wee hours. It also grows more conspicuous as the month progresses, brightening from magnitude 0.8 to 0.3. Mars moves steadily eastward through Virgo the Maiden during January. During the month's final week, it passes 5° north of that constellation's brightest star, 1st-magnitude Spica. The planet's ruddy glow appears slightly but noticeably brighter than the blue-white star.

As Mars approaches Earth, our neighbor becomes a more attractive target for telescope owners. The planet's apparent diameter grows by nearly 30 percent during January, from 6.9" to 8.9". The greater size makes it significantly easier to tease out subtle surface detail.

The next planet to rise is **Saturn**, which comes up shortly before 3 A.M. local daylight time January 1 and two hours earlier by month's end. The magnitude 0.6 planet is easy to identify against the relatively dim stars of Libra the Balance, especially after Scorpius rises — the Scorpion's head seems to point directly at it.

Saturn never fails to impress when you observe it through a telescope. For the best views, wait until the planet climbs higher around the start of twilight. The world-encircling rings — which span 37" and tilt 22° to our line of sight in mid-January — look magnificent through any scope.

A waning crescent Moon passes in front of Saturn on January 25, though this occultation occurs in a dark sky only from New Zealand and parts of the South Pacific Ocean. (In New Zealand, the event takes place the morning of the 26th.) From Christchurch, Saturn reappears at 13h02m UT, when the 36-percent-lit Moon lies 6° above the eastern horizon.

Venus disappeared into evening twilight at the end of 2013. Our neighbor passes between the Sun and Earth on January 11 and then climbs quickly into the morning sky by the month's final week. You can find the magnitude –4.8 planet low in the east during morning twilight. It makes a beautiful sight with naked eyes, binoculars, or a telescope. Any scope reveals Venus' crescent disk, which spans 52" and appears 12 percent lit.

You'll need keen eyesight, a clear sky, and an unobstructed western horizon to glimpse **Mercury** this month. The innermost planet reaches greatest elongation January 31, when it lies 18° east of the Sun. But this separation doesn't translate into much altitude for Southern Hemisphere observers. From 30° south latitude on the 31st, the planet stands just 5° high a half-hour after sunset. Those living closer to the equator will find Mercury a bit higher.

The starry sky

January is a great month to find your way around the sky. When I was young, after I made sure that I could recognize Crux the Southern Cross, my next goal was to use Orion's Belt as a pointer toward Sirius (to the southeast) and Aldebaran (to the northwest). Crux and Orion rank among the easiest constellations to identify and are two of the few that really look like the object, character, or creature after which they are named.

Quite a few constellations have fallen into disuse over the years. Many appeared on star maps long ago but have no place on charts today. Among these now-defunct constellations is one called "Limax." English naturalist John Hill invented it, along with 14 others, in 1754. He introduced them in his book *Urania: A Compleat View of the Heavens; containing the Antient and Modern Astronomy, in Form of a Dictionary*.

Hill described Limax as a naked snail or, in other words, a slug. He located the constellation in a fairly small part of sky just off Orion's southwestern corner (the upper left section as viewed from the Southern Hemisphere), close to the bright star Rigel. He described the location as being "between Orion, the Hare, and the Eridanus."

I don't blame you if you can't identify anything resembling a slug in this region — it certainly seems to exceed the limits of the imagination. Some scholars have suggested that Hill introduced these constellations for satirical purposes, though no one knows for sure.

STAR DOME

THE ALL-SKY MAP SHOWS HOW THE SKY LOOKS AT:
11 P.M. January 1
10 P.M. January 15
9 P.M. January 31

Planets are shown at midmonth



MAGNITUDES

- Sirius
- 0.0
- 1.0
- 2.0
- 3.0
- 4.0
- 5.0

- Open cluster
- Globular cluster
- Diffuse nebula
- Planetary nebula
- Galaxy

WorldMags.net



HOW TO USE THIS MAP: This map portrays the sky as seen near 30° south latitude. Located inside the border are the four directions: north, south, east, and west. To find stars, hold the map overhead and orient it so a direction label matches the direction you're facing. The stars above the map's horizon now match what's in the sky.

STAR COLORS: Stars' true colors depend on surface temperature. Hot stars glow blue; slightly cooler ones, white; intermediate stars (like the Sun), yellow; followed by orange and, ultimately, red. Fainter stars can't excite our eyes' color receptors, and so appear white without optical aid.

Illustrations by *Astronomy*: Roen Kelly

JANUARY 2014

Calendar of events

1 New Moon occurs at 11h14m UT

Pluto is in conjunction with the Sun, 19h UT

The Moon is at perigee (356,923 kilometers from Earth), 20h59m UT

4 Earth is at perihelion (147.1 million kilometers from the Sun), 12h UT

5 The Moon passes 5° north of Neptune, 2h UT

Jupiter is at opposition, 21h UT

7 The Moon passes 3° north of Uranus, 13h UT

8 First Quarter Moon occurs at 3h39m UT

Asteroid Pallas is stationary, 9h UT

11 Venus is in inferior conjunction, 12h UT

15 The Moon passes 5° south of Jupiter, 6h UT

16 The Moon is at apogee (406,532 kilometers from Earth), 1h53m UT

Full Moon occurs at 4h52m UT

23 The Moon passes 4° south of Mars, 6h UT

24 Last Quarter Moon occurs at 5h19m UT

25 The Moon passes 0.6° south of Saturn, 14h UT

28 Asteroid Melpomene is at opposition, 8h UT

Mars passes 5° north of Spica, 20h UT

29 The Moon passes 2° south of Venus, 3h UT

30 The Moon is at perigee (357,080 kilometers from Earth), 9h59m UT

New Moon occurs at 21h39m UT

31 Mercury is at greatest eastern elongation (18°), 10h UT

Venus is stationary, 19h UT

See tonight's sky in Astronomy.com's STARDOME

Astronomy magazine

Get the most in-depth astronomy magazine on the planet!

NASA/ESA/G. Illingworth and R. Bouwens (University of California, Santa Cruz)/The HUDF09 Team

Each monthly issue of ***Astronomy*** magazine is packed with all the tools you need to unlock the mysteries of the cosmos. Whether you're a beginner or an experienced stargazer — ***Astronomy*** can help you enjoy every minute under the stars!



Your subscription will include:

- Stunning images of the universe
- The latest in astronomy and space news
- Monthly columns from the best writers in the field
- Tips for locating stars, planets, and deep-sky objects
- All you need to know about the latest skywatching events

BONUS: Subscribers also get unlimited premium content on Astronomy.com!

Subscribe now *and* save!

Visit www.Astronomy.com

Outside U.S. and Canada, call 262-796-8776, x661

Mon.-Fri., 8:30 a.m.–4:30 p.m. CST. U.S. call 1-800-533-6644.

WorldMags.net

P18738

A3BA